

# *Coral Reef Monitoring*

## *Richardsons Ocean Center*

### *Summer 1995*

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A-

A very respectable effort. I think its principal weakness concerns <sup>poor</sup> incorporation of statistical results into the text of your Results section. My guess is that is due to a lack of experience with statistics rather than a lack of effort on your part. The paper could have been further improved if you had devoted more time to the interpretation of your observations (for example, that low coral cover was the result of harsh environmental conditions like waves or FW influx). Nonetheless, this is still a fine baseline from which others can work.

## *Abstract*

Coral reefs are the most productive areas of the ocean environment. In recent years, destruction of this beautiful and productive habitat has been increasing at an alarming rate, causing financial disturbance in the ecotourism business as well as environmental damage. Clive Wilkinson of the Australian Institute of Marine Science states that based on his pooled findings from around the world, at the present rate of reef destruction and decline there may be a net loss of sixty percent within the next twenty to forty years (Weber, 1993). This situation reflects a real need for long term monitoring studies like the one presently conducted at the study site of Kapoho Bay on the big island of Hawaii. In our research we attempted to establish baseline studies of a similar nature at the area of Richardsons Ocean Center located in Hilo, Hawaii. These studies can now be used in a future monitoring program to keep track of coral bleaching and overall reef health and productivity.

## *Introduction/background*

They have been called the rainforests of the ocean. In an environment

which has low productivity and can change in the blink of an eye, they are the shelters to run to. Reef coverage worldwide totals a mere .17 percent of the ocean floor but that same area proves home to nearly one fourth of all known marine organisms (Weber, 1993). Reefs are oases teeming with food resources and brilliantly colored flora and fauna. They help prevent soil erosion and turbidity currents. They are the coral reefs, and they are dying.

The most obvious indication of reef decline is coral bleaching. Thus, the degree of coral bleaching can serve as an indication for the overall condition of the ecosystem itself. The loss of coral ultimately signals a decline in the health and productivity of the entire reef community as well as those <sup>of</sup> other marine organisms and native populations that depend on the reef (Weber, 1993).

Reef building corals have a symbiotic relationship with certain types of zooxanthellae. This is what gives the coral its radiant coloration. The symbiotic zooxanthellae reside in the gastrodermal tissues of the coral. The zooxanthellae get housing and important nutrients like nitrogen and phosphates from the coral. In return, the algae photosynthetically produce carbon compounds which serve as nourishment for the coral. Also, the algae help to accelerate reef growth by causing more calcium carbonate to be produced to add to the coral skeleton (Brown et al., 1993).

When a coral bleaches, it is generally in response to some kind of environmental stress. This bleaching involves either the loss of the symbiont and/or a reduction in photosynthetic pigment in the zooxanthellae. Factors that can induce bleaching include; extremely high or low temperatures, sudden salinity changes, unusually high or low concentrations of light, UV radiation, and pollution (Buddemeir et al., 1993). Severe storms have also been indicated as a prime factor involved in coral bleaching. In particular this was seen in the mass bleaching events that occurred in the tropical eastern Pacific following the El Nino Southern Oscillation Event (ENSO) (Glynn et al., 1992). This event resulted in highly elevated temperatures which lead to the mass bleaching.

Corals can recover with time, but repetitive high stress levels can increase bleaching to the extent that the coral dies (Brown et al., 1993). This bleaching takes away from the reef's beauty and ecological stability.

Because of their high productivity and ecological importance, it is imperative that these biomes be studied and monitored to track the rate and effects of coral bleaching, consequently allowing for the opportunity to measure overall rates of reef decline over time. Although bleaching has been noted for Hawaii, there have as yet, been no mass bleaching events recorded. However, it is important to study bleaching as it happens to healthy coral in order to

determine the primary factors involved.

Coral reefs are an unquestionable asset, <sup>↑</sup>they hold immeasurable value for coastal communities acting as a natural buffer for erosional forces as well as providing an opportunity for many small nations to capitalize on tourism (Weber, 1993). Aside from these reasons, many native peoples derive all their major protein from the reef fish (Brown et al., 1993) and advances in technology have targeted reefs as a possible field for future scientific and medical developments and discoveries (Weber, 1993).

Given the recognized potential and importance of such an ecosystem, studies are now forming that will begin to work in combination with one another to global<sup>ly</sup> assess the degree of coral bleaching and overall reef depletion (Brown et al., 1993).

As of yet, coral bleaching cannot be chiefly attributed to any one source (Brown et al., 1993) but it is understood to be a response to environmental stresses, many of which can be traced to human development. In fact, studies are beginning to reflect that only those reefs with no or very limited contact with human influences are in truly good condition (Weber, 1993). One marine biologist working out of Belize attested to finding patches of dead coral possessing the uncanny shape of a diver's fin (Weber, 1993).

*I am not sure if the "big island" or "island of Hawaii" this is too redundant.*

Reef monitoring has already been done for several years at one location on the big island of Hawaii at Kapoho Bay. This study has enabled students to mark annual changes in such elements as percent coral coverage, species diversity and distribution, and the overall reef productivity at large (Quelch *et al.*, 1993).

Our designated study site was that of Richardsons Ocean Center.

Richardsons Ocean Center is located in Hilo on the big island of Hawaii.

Richardsons is moderately to heavily visited by both local patrons and tourists alike, making it a valuable resource to the Hilo community as well as the scientific community. There is a real need to monitor the health of this location, just as with Kapoho, due to its continued use and accessibility.

The goal of our research was to conduct a general bioassay of the area using fixed transect lines to sample the population. Using this <sup>method</sup> sample, the relative abundance of coral and macroinvertebrates were assessed. Our hypotheses were formulated based on surveys of the species and abundance of coral present, surveys of other substrate in this location, as well as surveys of the diversity and distribution of fish and epibenthic macroinvertebrates. Our main hypothesis was that there would be significant difference between overall abundance and distribution of coral/limu/substrate coverage, epibenthic

macroinvertebrates, and fish <sup>among</sup> along the three transect lines. Additional hypotheses were formulated as research progressed to assess whether a particular organism's abundance and distribution was dependent on type and amount of a specific coral. Also, we hypothesized that the visual coral cover estimation would positively correlate with photoquadrant data.

These baseline studies at Richardsons will provide a foundational profile of the area for future long term monitoring comparison studies that will reflect the ongoing conditions of the reef at Richardsons.

### *Methods and Materials*

The research involved the sampling of the reef community. Due to its size, a complete census of the reef community would be costly temporally as well as financially. The sampling was thus taken by randomly selecting three fixed and connected transect lines in an area of the reef at Richardsons. The lines themselves were ten meters long and composed of Kevlar rather than nylon which tends to stretch more readily. This results in a more accurate line length. The three transect lines were placed at 1) 145 degrees, 2) 100 degrees, and 3) 85 degrees <sup>magnetic</sup> ~~relative to lifeguard station~~ (refer to ~~figure~~ <sup>Figure</sup> 1). The lines <sup>trans-</sup>are fixed to metal pins anchored into the substrate. The transect lines were divided into meter long segments.

The research team surveyed the organisms and coral found along these lines using snorkel and skin diving techniques. The quantitative studies of the fish and macroinvertebrates as well as the coral coverage estimations will provide a limited profile of the selected study area for future reference concerning continued monitoring studies along these same transect lines.

On lines one through three, on the right sides only, a percent cover estimation of coral and substrate was calculated by using a  $1/4 \text{ m}^2$  quadrat. The quadrat was broken into four subquadrants. The quadrat was made of PVC piping, drilled with holes and slightly weighted for easy placement and positioning. There <sup>was</sup> a total of twenty quadrant stations on each transect line. The visual estimation was conducted for coral (specific species), limu (specific species), and substrate (sand and rock). Each estimation was conducted only once for each line.

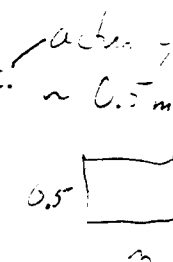
On the right side only of all transect lines, a quadrant search was conducted for epibenthic macroinvertebrates. The search employed a  $\text{m}^2$  quadrat of the same material as that of the  $1/4 \text{ m}^2$  used in the percent coverage estimations. The quadrat was placed and positioned at every meter mark along the line. Members of the research team would <sup>breath-hold</sup> ~~skin~~ dive to assess and record the number of organisms that appeared within the quadrat's <sup>borders</sup> parameters. This



was a complete quadrat search and every attempt was made to ensure that any hidden or rare organisms were not overlooked. Slash marks or numbers for each organism found were placed next to its respective name on the data sheets provided (Figure 2). These thirty quadrant stations along the transect lines will be a valuable tool for quantifying species diversity and distribution at the study site.

The analysis of fish abundance and diversity was done by counting the number of fish of both sides of each transect line, at a distance of three meters per side. Fish in the water column were counted first, and recorded on the data sheets by team members. Then, the members <sup>swim</sup> ~~proceeded to swim~~ along the line recording those fish that appeared to be hiding in the cracks and crevices.

Coral cover was also estimated using photographic images. The photoquadrants were taken using a Nikonos camera, fixed within a  $m^2$  quadrat. The pictures, taken on both sides of all lines, were <sup>taken with slide film.</sup> ~~transferred onto slides~~. These slides were then projected onto a viewing surface where an overlay equipped with fifty random points was employed to analyze coral/limu/substrate coverage. Team members studied the points and determined what coral species or other substrates were located at each number. The sixty slides will be used for future reference and comparison in the continued study of this area. In the



future, these slides will be placed in a permanent file in order for the degree of coral bleaching to be studied using both manual assessment as well as a scientific Microsoft computer program called Sigma Scan.

All data and results were quantified using Microsoft programs. Lotus 1-2-3 was employed to make basic mean and standard deviation calculations, as well as preparing material to be imported into Minitab. Minitab and QuattroPro were used to determine statistical variations and generate graphics. By using these graphs, it became easier to see if any significant correlations occurred between the lines. Using Minitab we were able to look for trends and run One-Way Analyses of Variance (ANOVA) on and across our transect lines. In order to determine that our correlations were significant, a <sup>p</sup> value ~~"p"~~ <sup>of 0.05 was set</sup> ~~was assessed~~ for each Anova. This value determined whether or not we could accept or reject our null hypotheses.

All of <sup>these</sup> ~~this~~ data can now be used as an effective foundation for future monitoring studies at Richardsons Ocean Center reef site. Our studies ~~concluded what could be~~ <sup>is</sup> the initial phase of an annual monitoring project like the one conducted presently at the Kapoho Bay site.

## *Results*

The ~~raw~~ data from our research showed total area coverage of

coral/limu/substrate, diversity and abundance of macroinvertebrates, and also gave a limited record of fish found at the study site.

Data reflected that rock was the most dominant substrate on all three lines <sup>significantly more as I recall from ANOVAS</sup> (Table 1). <sup>5,3</sup> The coral species found at Richardsons Ocean Center were; *P. lobata*, *P. compressa*, *P. meandrina*, and *M. verrucosa* (Fig.3). Of these coral species, *P.lobata* was found to have the greatest total amount of area coverage for all three lines, with line two having the highest abundance (Fig.3-6).

The data concerning the macroinvertebrates showed that *Spirobranchus giganteus* and *Echinometra mathaei* were the dominant species found along all transect lines. The calculated numbers for *S. giganteus* for all three lines totalled 330 individuals. The total number of *E. mathaei* was 147 individuals (Table 2). *S. giganteus* were found in the greatest numbers along line two (Fig. 7). *E. mathaei* were most numerous along line one (Fig. 8). Less numerous but also seen species included; *Sabellastarte sanctijosephi* (5), *Conus spp.* (7), Hermit crabs (7), *Echinometra oblonga* (15), *Echinothrix calamaris* (10), *Echinothrix diadema* (9), *Heterocentrotus mammillatus* (4), *Tripneustes gratilla* (3), *Holothuria atra* (2), *Ophicoma spp.* (3), *Lanice conchilega* (1), and Limpet (1).

Our fish transect showed that the top five species recorded on site were;

Significant  
ANOVAS  
sp. 3/11/1

Conclusion  
because  
was not  
recorded  
by them  
ditto

*Thallosoma duperrey*, *Plectroglyphidodon imparipennis*, *Plectroglyphidodon johnstonianus*, *Ostracion meleagris*, *Stegastes fasciolatus*. (Figs.9 -12)

Also seen on the lines were; *Coris gaimard* (juvenile), *Acanthurus achilles*, *Acanthurus nigroris*, *Abudefduf abdominalis*, *Labroides phthiophagus*, *Chaetodon lunula*, *Ctenochaetus hawaiiensis*, and *Gymnothorax* spp.

## Discussion and Conclusions

Based on our results and observations, we found we had to accept our null hypotheses due to the ANOVA comparison of the three lines giving "p" values .245 for percent cover of *P. meandrina* and .263 for *P. lobata* which were not considered significant (Table 3). *P. lobata* and *P. meandrina* were found to be the dominant coral species covering all three lines (Fig.3).

However, rock had the <sup>a significantly higher (P < 0.001)</sup> highest percent area coverage of all substrates on all three lines ( Figs. 4-7). This data <sup>was</sup> ~~was~~ also supported by the results of our photoquadrant analysis ( Figs.13-16).

A <sup>significant positive</sup> ~~direct~~ correlation <sup>(P < 0.02 - 0.05)</sup> was found between these photquadrant data and that of the visual percent coverage estimations. <sup>for all 3 lines (Figs 18-20).</sup> An ~~ANOVA~~ <sup>Regression</sup> of the data showed that the estimations and photoquadrant data had enough of a match to be considered significant ( Figure 17). Regression Plots showed a clear, graphical representation of this correlation (Fig. 18-20). Based on <sup>this</sup> ~~this~~ data we were able

to show

to reject our null hypothesis. The correlation increased confidence that this visual estimation was a valid tool for determining total area coverage of specific species and abundance.

The coral/limu/substrate analysis showed *P. Lobata* as having been the most dominant species along the transect lines, with line two having the highest percentage (Figure 21). This lead us to draw a possible hypothesis that the concentrations of *Spirobranchus giganteus* would be higher on line two. An ANOVA produced a "p" value of .003 which can be considered significant allowing us to reject our null hypothesis (Fig.22). There was also a significant "p" value of .026 for line three. (Fig 22). A Regression Plot of line two shows a clear, graphical representation of the correlation. (Fig. 23).

The high numbers of *E. mathaei* (Fig. 24-27) lead us to hypothesize that perhaps there was a correlation between the amount of rock coverage and number of individuals. However, the graphical representations reveal negative correlations and insignificant "p" values (Fig. 28-30).

Our research was an attempt to establish a profile of the reef community of the Richardsons Ocean Center site. We postulate that our "p" values could have been affected by the small sample size and relatively high variance between the lines. In addition there is always the danger of bias recording

This is the appropriate place to speculate why *Spirobranchus* is more abundant on line two (i.e. obligate habitat?) and why *E. mathaei* may be increasing on line three.

concerning organism counts. One way to minimize this would be to increase the number of field hours and/or sample size.

Another problem encountered at Richardsons Ocean Center was the amount of surge on a given day. Though every possible effort was made to maintain accuracy, positioning of the quadrants were almost always affected by ~~this~~ *water motion*.

In the future of this program, Sigma Scan will be used in the determination of the degree of coral bleaching so that there will be a permanent record of Richardsons, housed on slide files. Also, future groups may want to measure salinity and temperature levels in and around the reef. This may show correlations between the bleaching and these factors.

It is only through studies like this one and that of Kapoho, that enough knowledge can be gained in order to create corrective or preventative measures to save the future of the coral reefs.

## *Literature Cited*

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Buddemeier, Robert W. and Daphne G. Fautin. 1993. Coral Bleaching as an Adaptive Mechanism: a testable hypothesis. *Bioscience*. 43 (5): 320-327.

Glynn, Peter W. 1991. Coral reef bleaching in the 1980's and possible Connections with Global Warming. *Trends in Ecology and Evolution* 6 (6): 175-179.

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Quelch, Cyndi, James Gawlowski, and John Derby. <sup>1993</sup> Coral Reef Monitoring, Kapoho Bay, Hawaii. ~~1993~~. <sup>Mar 366 project, Summer Session 1993.</sup>

Weber, Peter. 1993. Coral reefs face the Threat of Extinction. *USA Today* 121 (2576): 63-65.

TABLE 1

Percent Coverage of Substrate Sums

Percent Coverage of Substrate Sums

Line	lob-s	cor-s	mean-s	vert-s	lead-s	sand-s	rock-s
1	0	0	500	0	0	0	2000
2	0	0	0	0	0	0	2350
3	0	0	0	0	375	50	1625
4	0	0	0	0	0	25	1444
5	0	0	0	0	15	0	1431
6	0	0	0	0	50	0	1844
7	0	0	0	0	0	245	2225
8	0	0	13	0	31	469	1163
9	0	0	0	0	0	0	1488
10	0	0	0	0	0	31	1275
11	0	0	469	0	0	1000	338
12	0	0	0	0	50	531	875
13	0	0	0	0	38	175	2219
14	0	0	0	0	31	269	2169
15	0	0	0	0	0	375	2125
16	0	0	0	0	0	1125	1331
17	0	0	0	0	200	444	1606
18	0	0	0	0	25	31	1750
19	0	0	0	0	44	0	2263
20	0	0	131	0	0	125	2244
21	0	0	350	0	25	500	1625
22	0	0	0	0	131	325	1550
23	0	0	0	125	50	250	1850
24	0	0	0	225	75	388	1875
25	0	0	0	0	75	400	1625
26	0	0	0	0	225	725	1350
27	0	0	0	0	150	900	950
28	0	0	0	0	0	1050	1450
29	0	0	125	0	75	50	1150
30	0	0	0	0	250	600	1650
31	0	0	0	0	50	275	2175
32	0	0	150	0	125	225	1900
33	0	0	0	0	138	250	1750
34	0	0	0	0	0	50	2325
35	0	0	575	0	50	125	1750
36	0	0	0	75	150	0	0
37	0	0	0	263	150	0	63
38	0	0	0	0	50	0	400
39	0	0	450	0	263	0	363
40	0	0	0	0	0	75	1075
41	0	0	0	0	0	50	2450
42	0	0	0	0	125	0	2225
43	0	0	0	0	300	150	1625
44	0	0	0	0	950	0	1250
45	0	0	0	0	50	375	575
46	0	0	0	0	0	875	1625
47	0	0	0	0	50	550	1800
48	0	0	0	0	200	0	2150
49	0	0	300	0	100	0	1825
50	0	0	0	0	0	875	1325
51	0	0	0	0	0	1100	800

Line	lob-s	cor-s	mean-s	vert-s	lead-s	sand-s	rock-s
52	0	0	1125	0	0	0	400
53	0	0	0	0	0	0	1600
54	0	0	0	0	0	0	1600
55	0	0	0	0	0	0	1600
56	0	0	0	0	0	0	1600
57	0	0	0	0	0	0	1600
58	0	0	0	0	0	0	1600
59	0	0	0	0	0	0	1600
60	0	0	0	0	0	0	1600
61	0	0	0	0	0	0	1600
62	0	0	0	0	0	0	1600
63	0	0	0	0	0	0	1600
64	0	0	0	0	0	0	1600
65	0	0	0	0	0	0	1600
66	0	0	0	0	0	0	1600
67	0	0	0	0	0	0	1600
68	0	0	0	0	0	0	1600
69	0	0	0	0	0	0	1600
70	0	0	0	0	0	0	1600
71	0	0	0	0	0	0	1600
72	0	0	0	0	0	0	1600
73	0	0	0	0	0	0	1600
74	0	0	0	0	0	0	1600
75	0	0	0	0	0	0	1600
76	0	0	0	0	0	0	1600
77	0	0	0	0	0	0	1600
78	0	0	0	0	0	0	1600
79	0	0	0	0	0	0	1600
80	0	0	0	0	0	0	1600



TABLE 2

Integrated Sum

Integrated Sum

	143	144	145	146	147	148	149	150
Case	Conc-S	Cap-S	Sp. Co-S	Jace-S	Term-S	Match-S	2. Long-S	
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	151	152	153	154	155	156	157	158
Case	Conc-S	Cap-S	Sp. Co-S	Jace-S	Term-S	Match-S	2. Long-S	
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Integrated Sum

	151	152	153	154	155	156	157
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	151	152	153	154	155	156	157
Case	Conc-S	Cap-S	Sp. Co-S	Jace-S	Term-S	Match-S	2. Long-S
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# TABLE 3

## One-Way Analysis of Variance

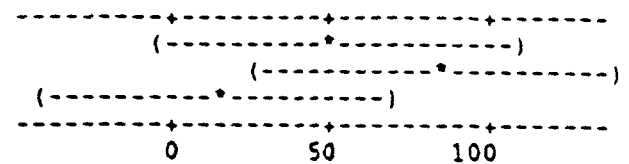
Analysis of Variance on mean-s

Source	DF	SS	MS
Line	2	45667	22834
Error	57	902698	15837
Total	59	948365	

F 1.44 p 0.245

Level	N	Mean	StDev
1	20	51.5	116.9
2	20	82.5	171.3
3	20	15.0	67.1

Individual 95% CIs For Mean  
Based on Pooled StDev



Pooled StDev = 125.8  
MTB > Oneway 'lob-s' 'Line'.

## One-Way Analysis of Variance

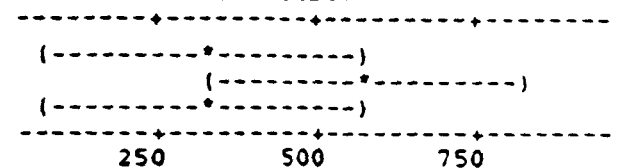
Analysis of Variance on lob-s

Source	DF	SS	MS
Line	2	833260	416630
Error	57	17366876	304682
Total	59	18200134	

F 1.37 p 0.263

Level	N	Mean	StDev
1	20	315.7	396.5
2	20	567.2	757.8
3	20	318.7	427.3

Individual 95% CIs For Mean  
Based on Pooled StDev



Pooled StDev = 552.0

Richardsons Ocean Center  
Transect Bolt Locations  
(Not Drawn To Scale)

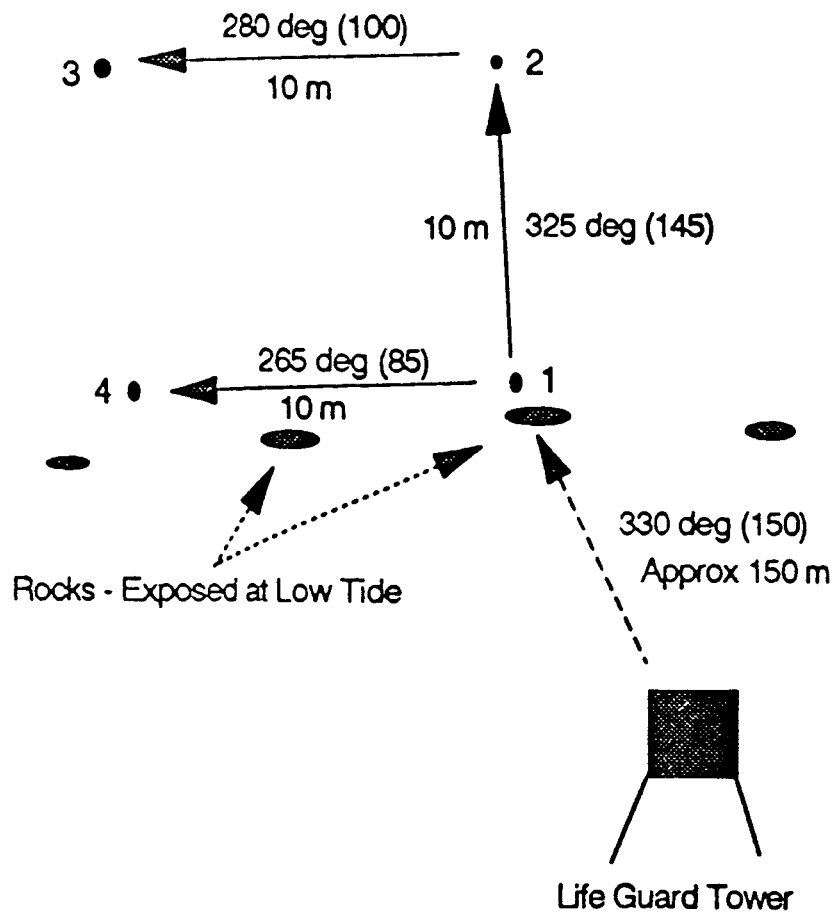


FIG. 1

# Fish Strip Transect

Date:	Location:	Trans Length:		Trans Width:	
Diver:	Time In:	Time Out:			
		Transect:		Transect:	
Species		Count	Sum	Count	Sum
<b>Butterfly fishes</b>					
<i>Chaetodon auriga</i>	Threadfin				
<i>Chaetodon quadrimaculatus</i>	Four spot				
<i>Chaetodon lunula</i>	Raccoon				
<i>Chaetodon miliaris</i>	Milletseed				
<i>Chaetodon ornatissimus</i>	Ornate				
<i>Chaetodon multicinctus</i>	Multiband				
<i>Forcipinger flavissimus</i>	Longnose				
<b>Damselfishes</b>					
<i>Abudefduf abdominalis</i>	Sergent				
<i>Plectroglyphidodon imparipennis</i>	Brighteye				
<i>Plectroglyphidodon johnstonianus</i>	Blue-eye				
<i>Stegastes fasciatus</i>	Gregory				
<i>Chromis hanui</i>	Chocolate dip				
<i>Dascyllus albisella</i>	Domino				
<b>Wrasses</b>					
<i>Labroides phthiophagus</i>	Cleaner				
<i>Coris gaimard</i>	Yellowtail				
<i>Coris flavovittata</i>	Yellowstripe				
<i>Thallosoma ballieui</i>	Blacktail				
<i>Thallosoma duperrey</i>	Saddle				
<b>Parrotfishes</b>					
<i>Scarus sordidus</i>	Bullethead				
<i>Scarus perspicillatus</i>	Spectacled				
<b>Surgeonfishes</b>					
<i>Acanthurus triostegus</i>	Convict				
<i>Acanthurus achilles</i>	Achilles				
<i>Acanthurus nigrofusus</i>	Brown				
<i>Acanthurus nigroris</i>	Blueline				
<i>Ctenochaetus strigosus (Kole)</i>	Gold-ring				
<i>Ctenochaetus hawaiiensis</i>	Black				
<i>Zebrasoma flavescens</i>	Yellow tang				
<i>Zanclus cornutus</i>	Moorish Idol				
<b>Triggerfish</b>					
<i>Rhinecanthus rectangulus</i>	Reef				
<i>Rhinecanthus aculeatus</i>	Lagoon				
<i>Sufflamen bursa</i>	Lei				
<b>Puffers &amp; Trunkfish</b>					
<i>Ostracion meleagris</i>	Spotted boxfish				
<i>Arothron meleagris</i>	Spotted puffer				

"SAMPLE DATA SHEET"

FIG. 2

# Epibenthic Biota and Substrate

Richardsons Ocean Center

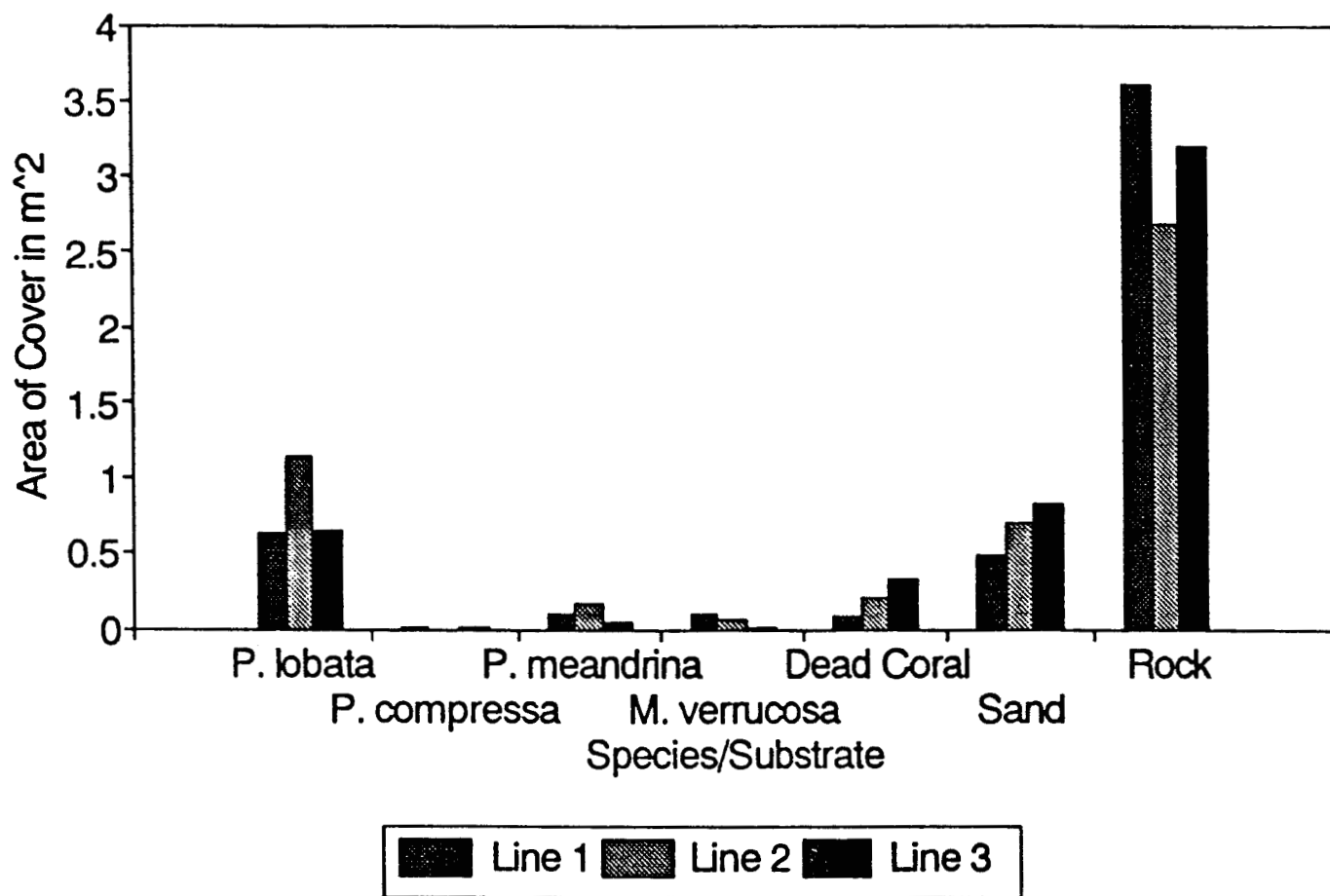


FIG. 3

# Epibenthic Biota and Substrate

Richardsons Ocean Center

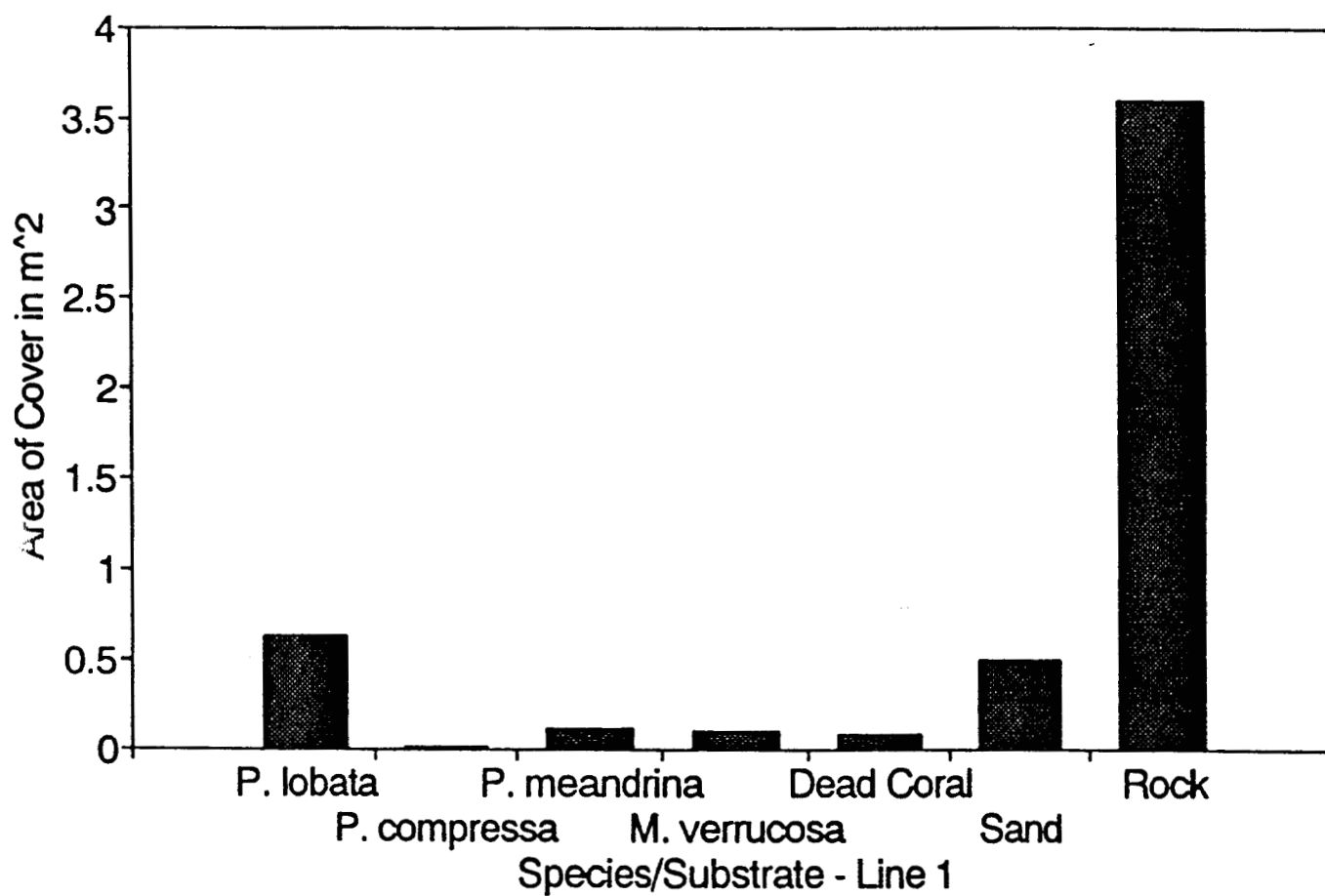


FIG. 4

# Epibenthic Biota and Substrate

Richardsons Ocean Center

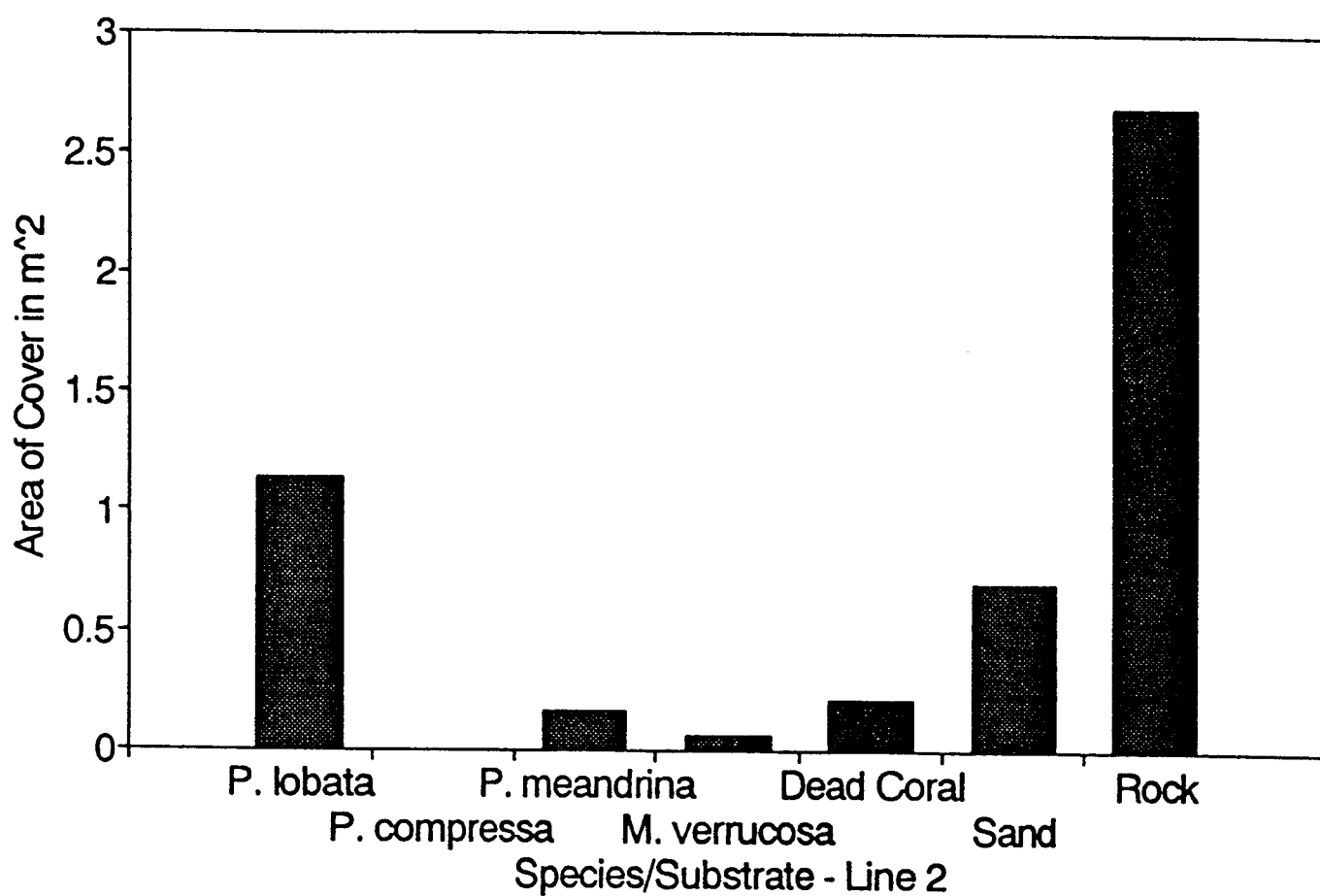


FIG. 5

# Epibenthic Biota and Substrate

Richardsons Ocean Center

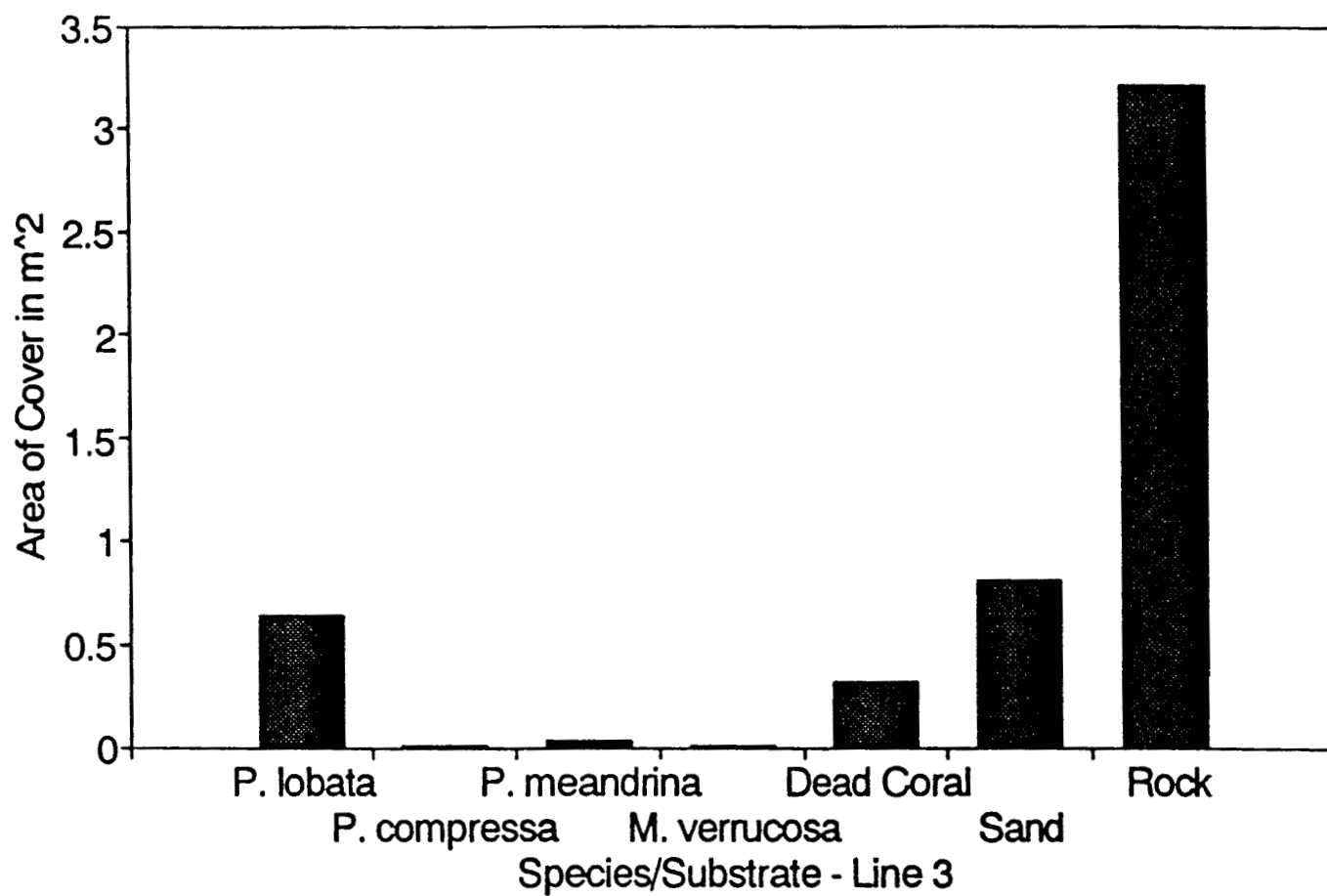


FIG. 6



Richardsons Ocean Center

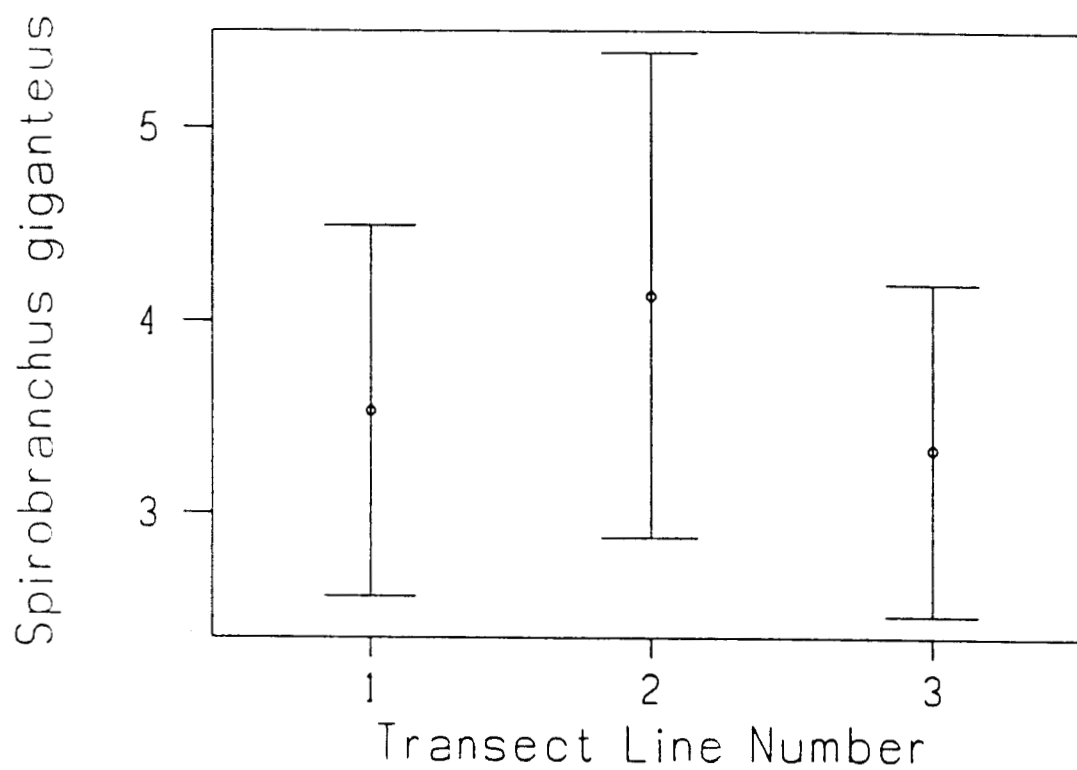


FIG. 7

Richardsons Ocean Center

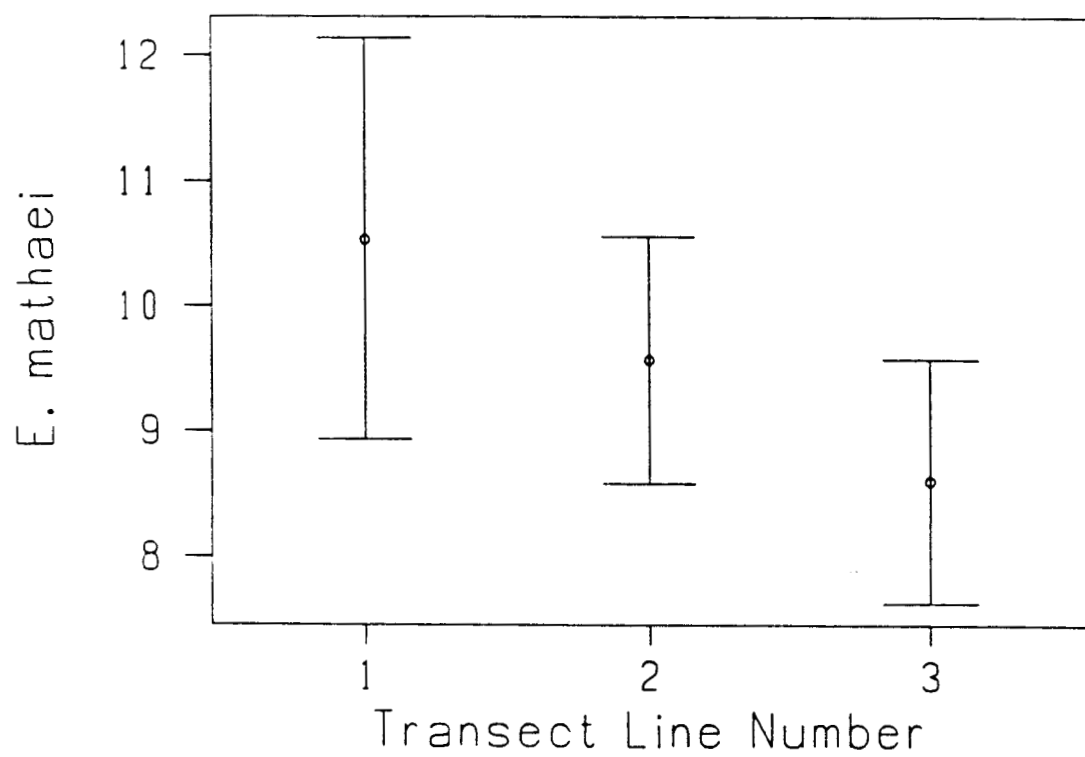


FIG. 8

# Fishes

Richardson Ocean Center

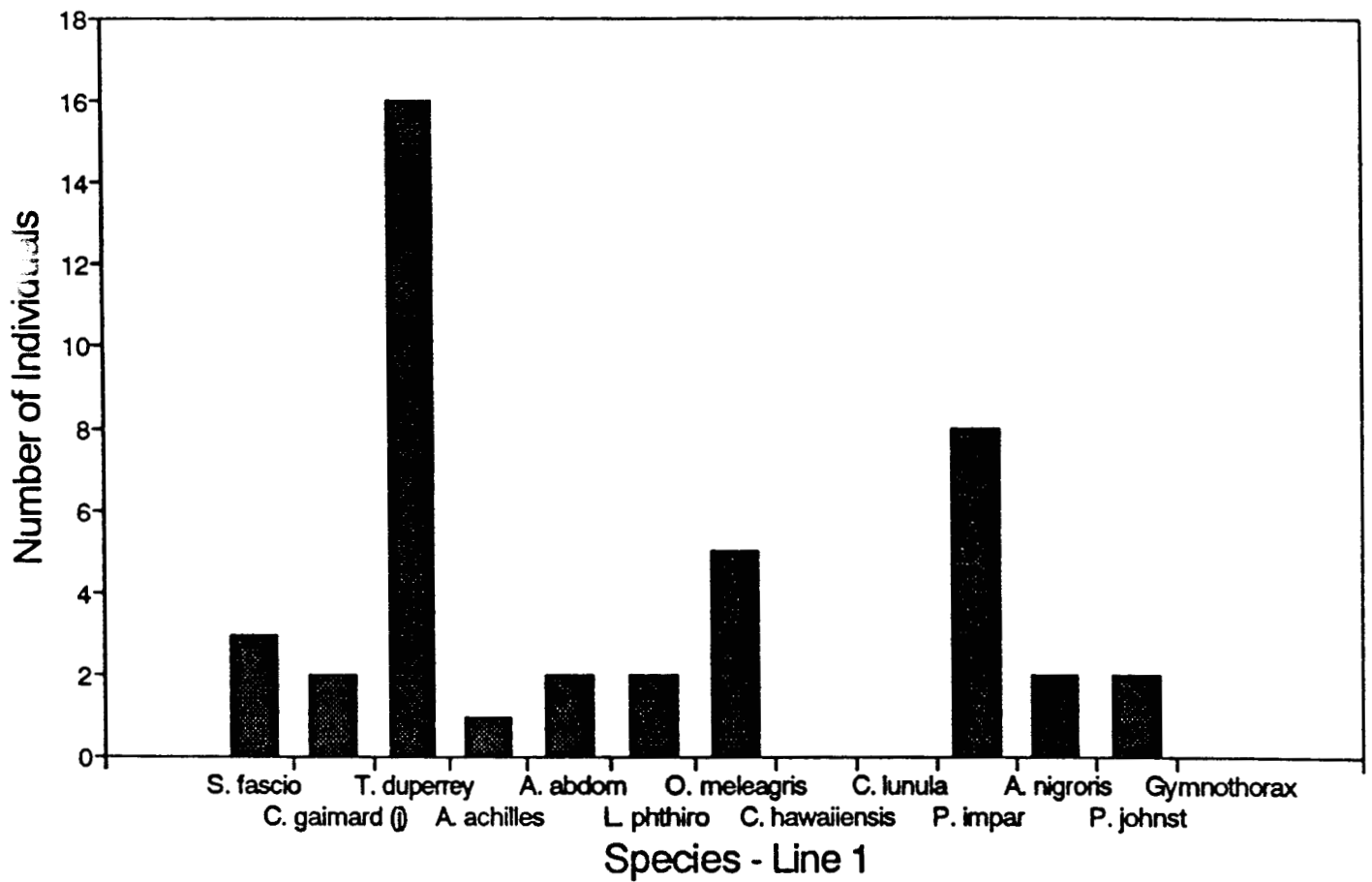


FIG. 9

# Fishes

Richardson Ocean Center

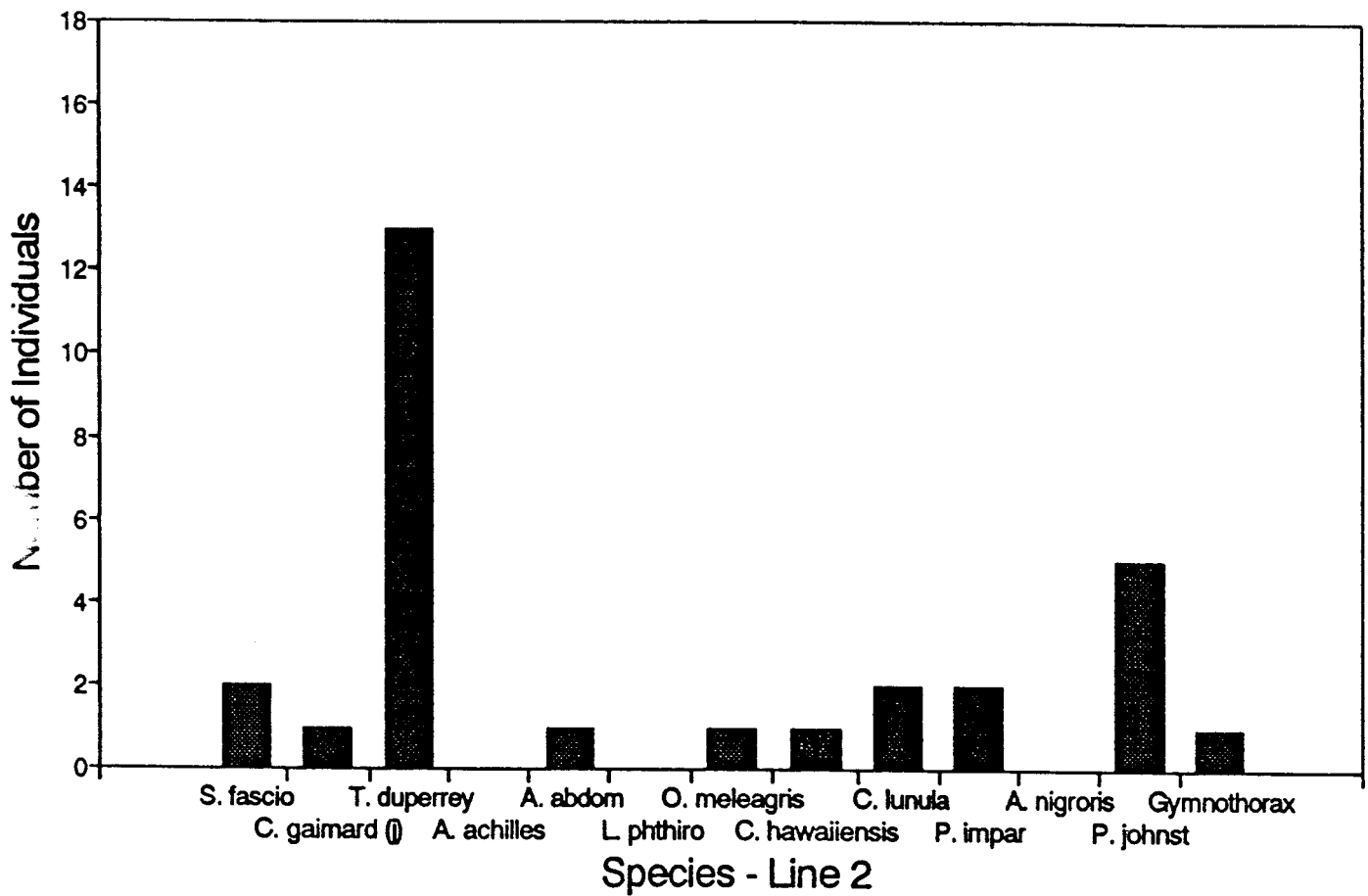


FIG. 10

# Fishes

Richardson Ocean Center

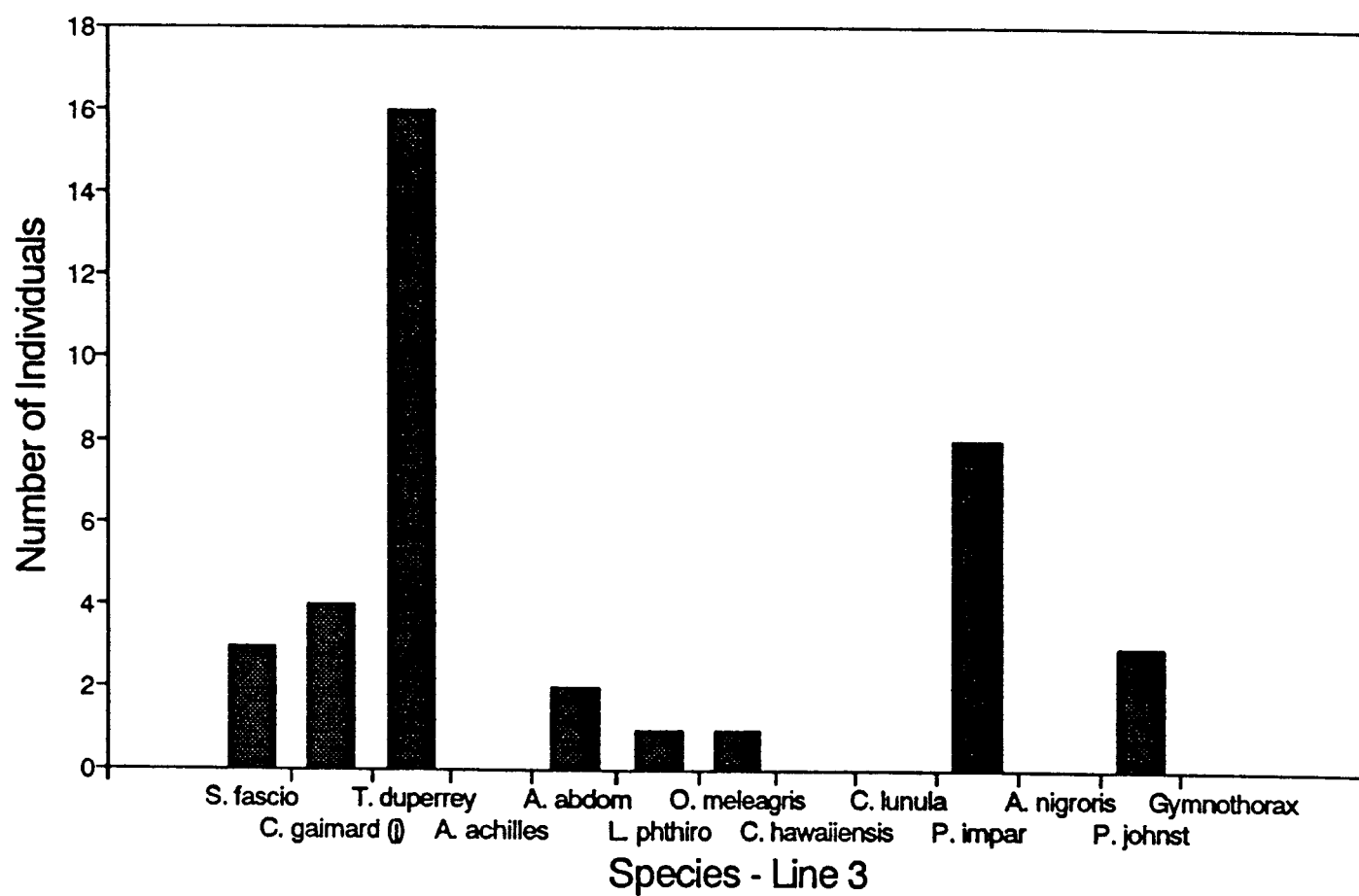


FIG. 11

# Fishes

Richardson Ocean Center

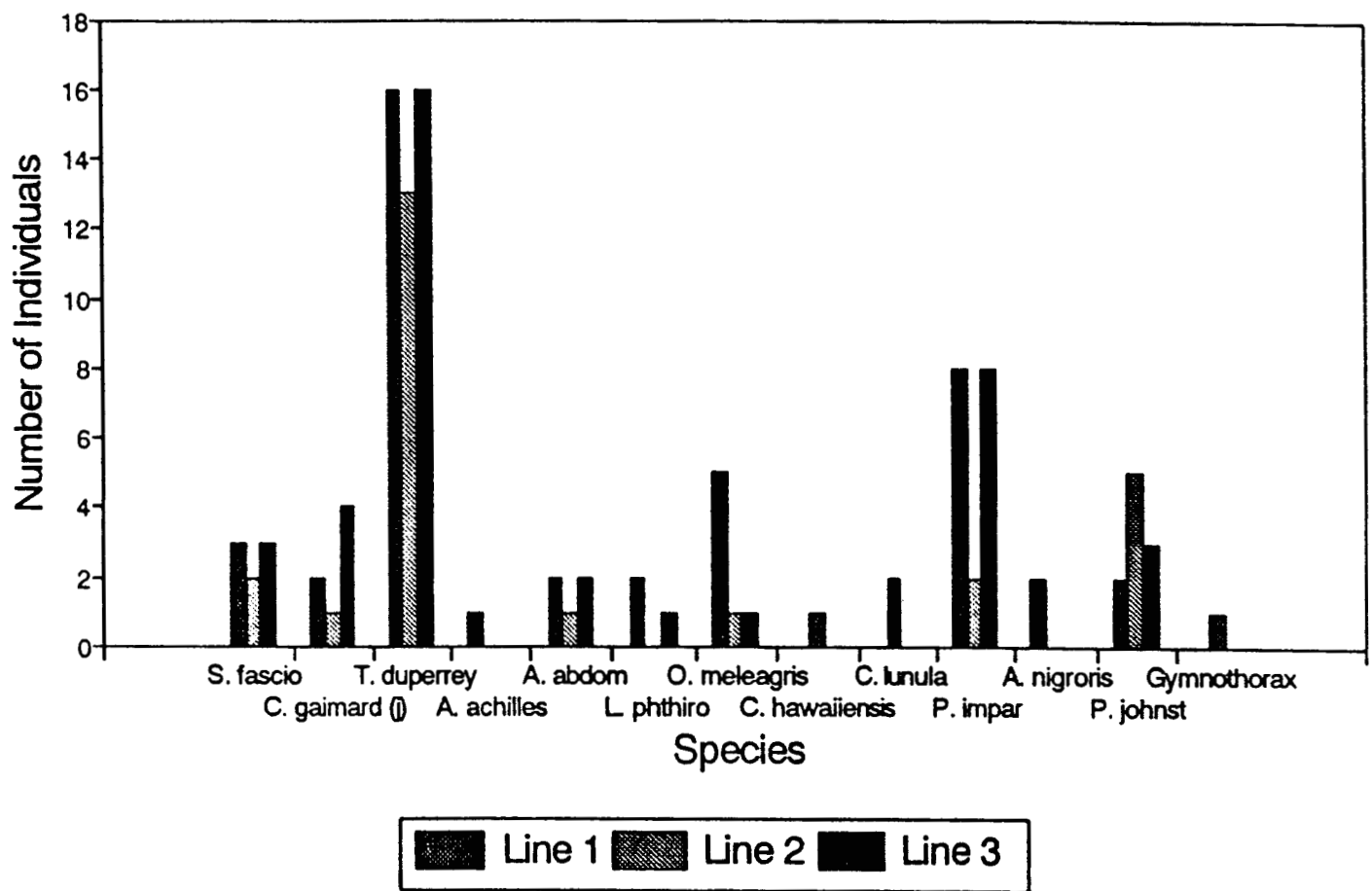


FIG. 12

# Epibenthic Biota and Substrate

Richardsons Ocean Center

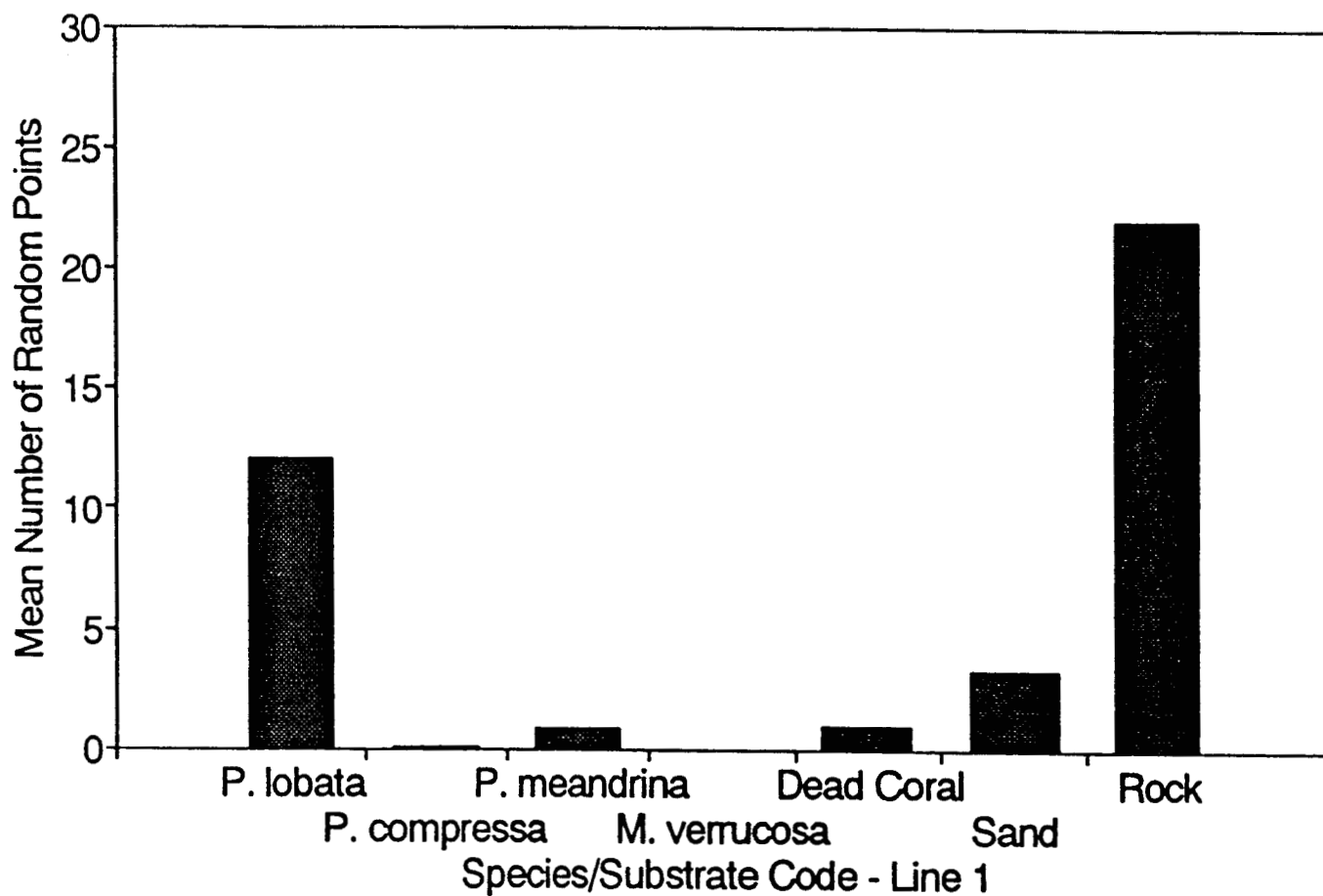


FIG. 13

# Epibenthic Biota and Substrate

Richardsons Ocean Center

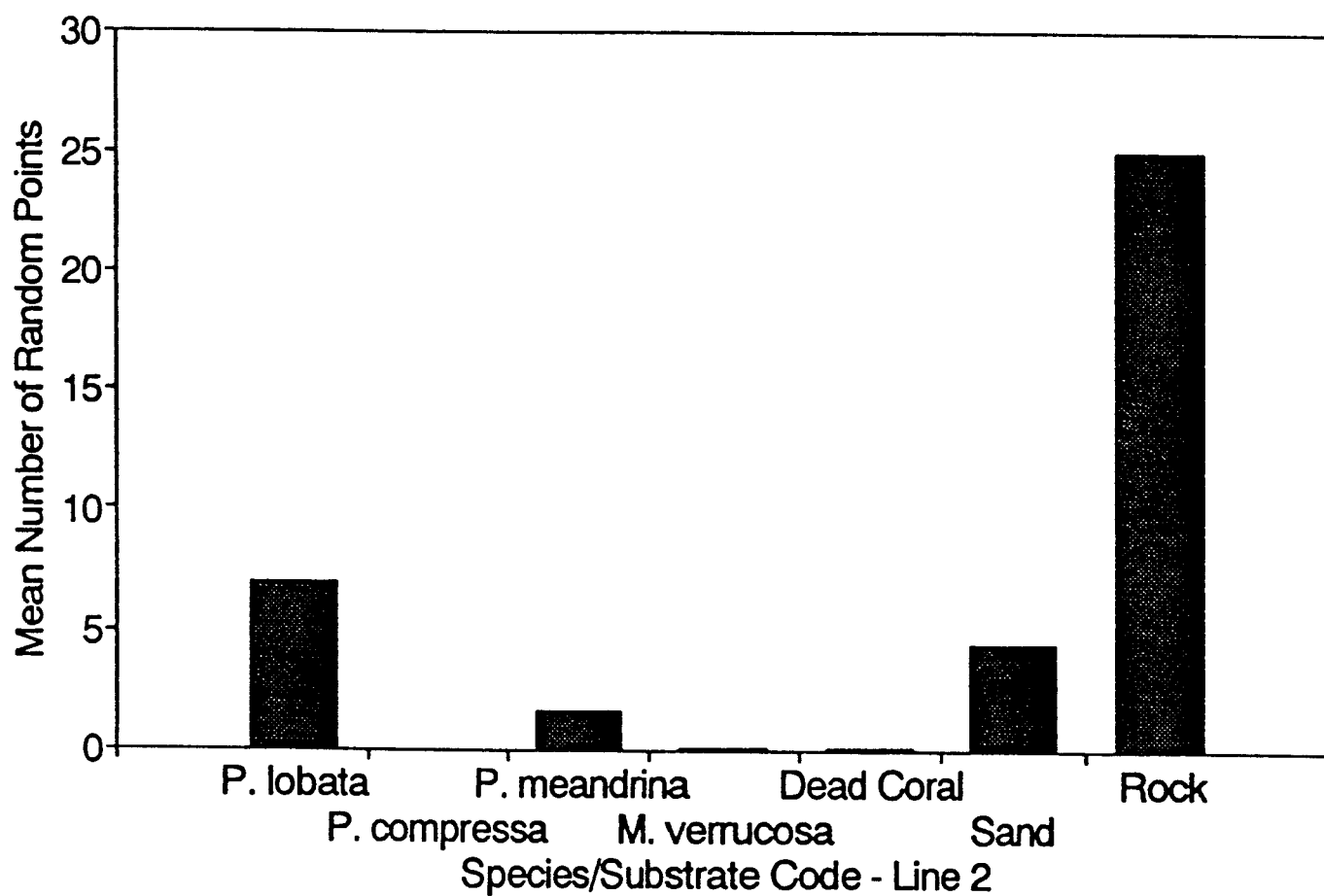


FIG. 14



# Epibenthic Biota and Substrate

Richardsons Ocean Center

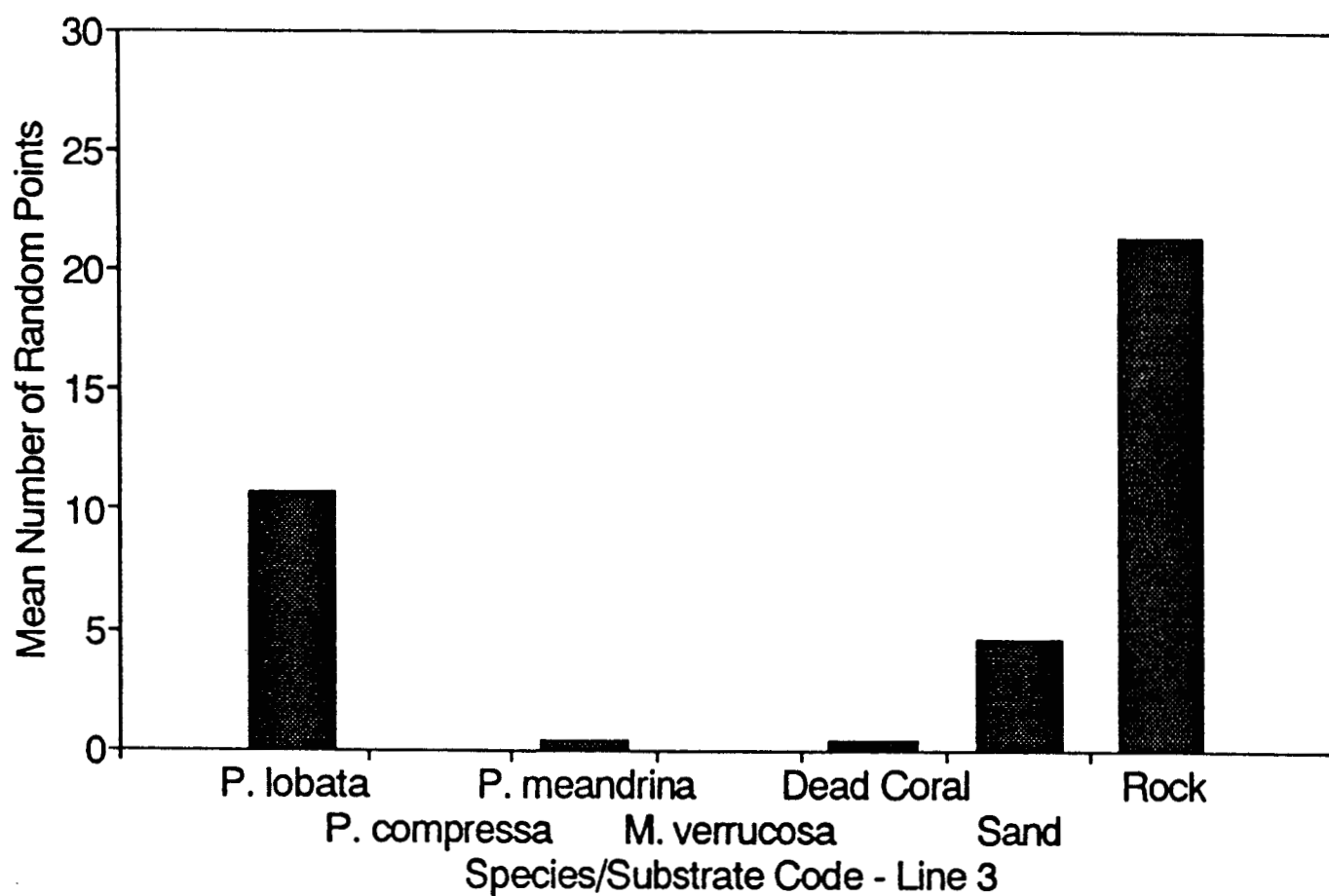


FIG. 15

# Epibenthic Biota and Substrate

Richardsons Ocean Center

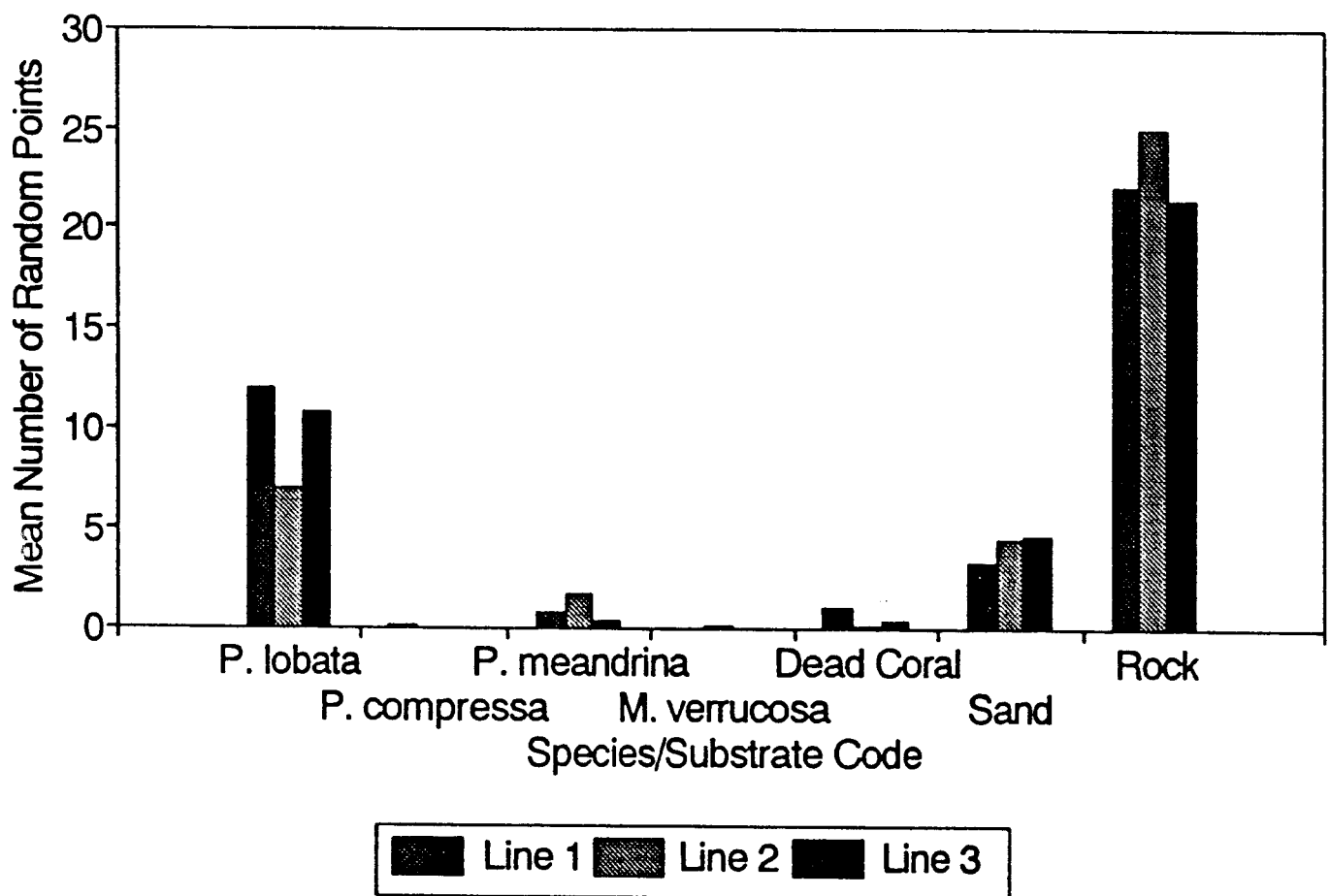


FIG. 16

## Regression Analysis

The regression equation is

$$\text{PtsLob1} = -0.827 + 0.0152 \text{ AreaLob1}$$

Predictor	Coef	Stdev	t-ratio	p
Constant	-0.8267	0.7956	-1.04	0.329
AreaLob1	0.0152226	0.0008669	17.56	0.000

s = 1.823      R-sq = 97.5%      R-sq(adj) = 97.2%

### Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	1025.0	1025.0	308.36	0.000
Error	8	26.6	3.3		
Total	9	1051.6			

MTB > %Fitline 'PtsLob1' 'AreaLob1';

SUBC> Confidence 95.0.

Executing from file: C:\MTBWIN\MACROS\Fitline.MAC

Macro is running ... please wait

MTB > Regress 'PtsLob2' 1 'AreaLob2';

SUBC> Constant.

## Regression Analysis

The regression equation is

$$\text{PtsLob2} = -0.44 + 0.00859 \text{ AreaLob2}$$

Predictor	Coef	Stdev	t-ratio	p
Constant	-0.444	1.761	-0.25	0.807
AreaLob2	0.008589	0.001036	8.29	0.000

s = 4.147      R-sq = 89.6%      R-sq(adj) = 88.3%

### Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	1182.5	1182.5	68.75	0.000
Error	8	137.6	17.2		
Total	9	1320.1			

### Unusual Observations

Obs.	AreaLob2	PtsLob2	Fit	Stdev.Fit	Residual	St.Resid
8	2275	11.00	19.10	1.77	-8.10	-2.16R
10	2650	30.00	22.32	2.05	7.68	2.13R

## Regression Analysis

The regression equation is

$$\text{PtsLob3} = 3.13 + 0.00874 \text{ AreaLob3}$$

Predictor	Coef	Stdev	t-ratio	p
Constant	3.129	2.929	1.07	0.317
AreaLob3	0.008739	0.003198	2.73	0.026

s = 6.651      R-sq = 48.3%      R-sq(adj) = 41.8%

### Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	330.22	330.22	7.47	0.026
Error	8	353.88	44.23		
Total	9	684.10			

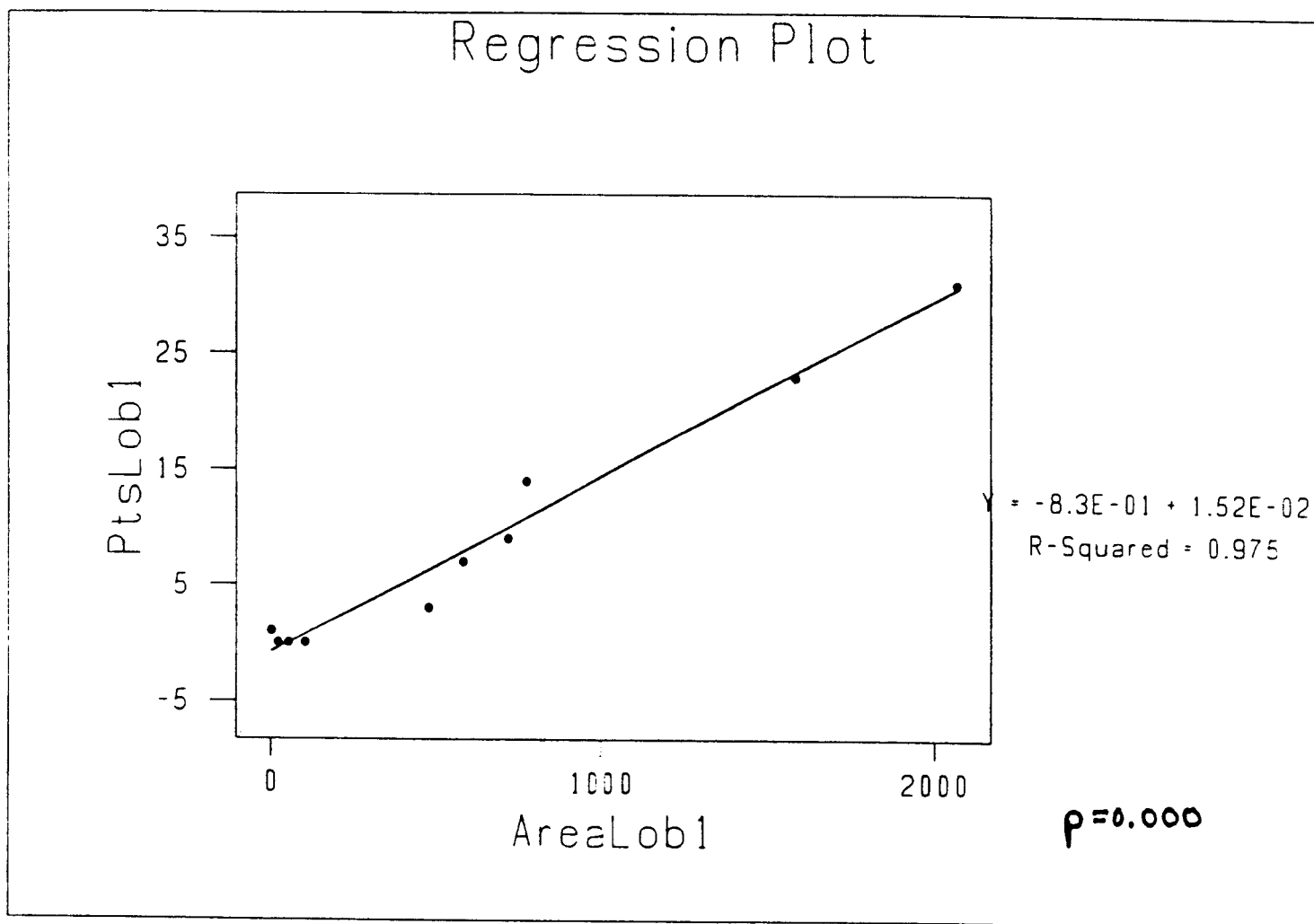


FIG. 18

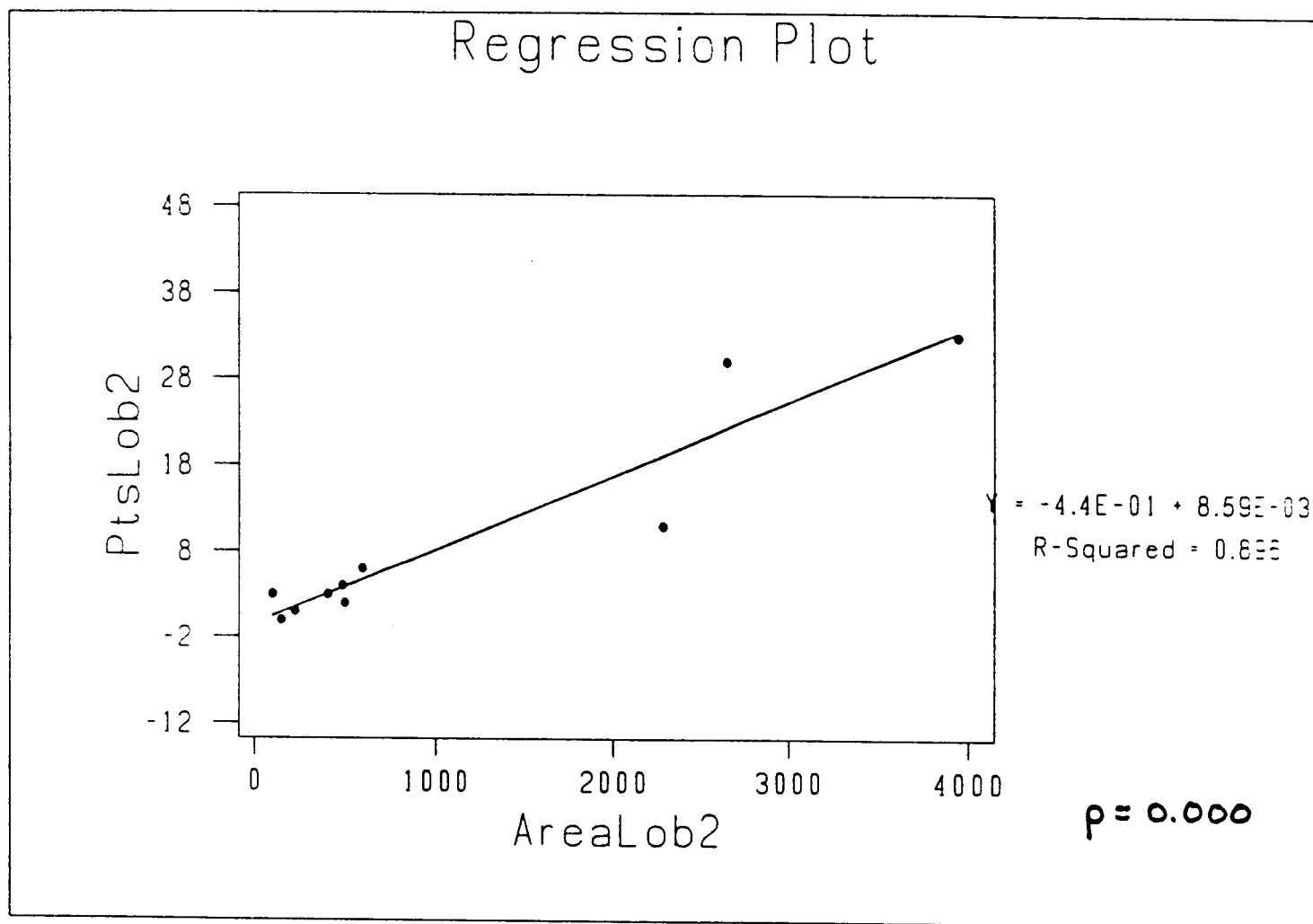


FIG. 19

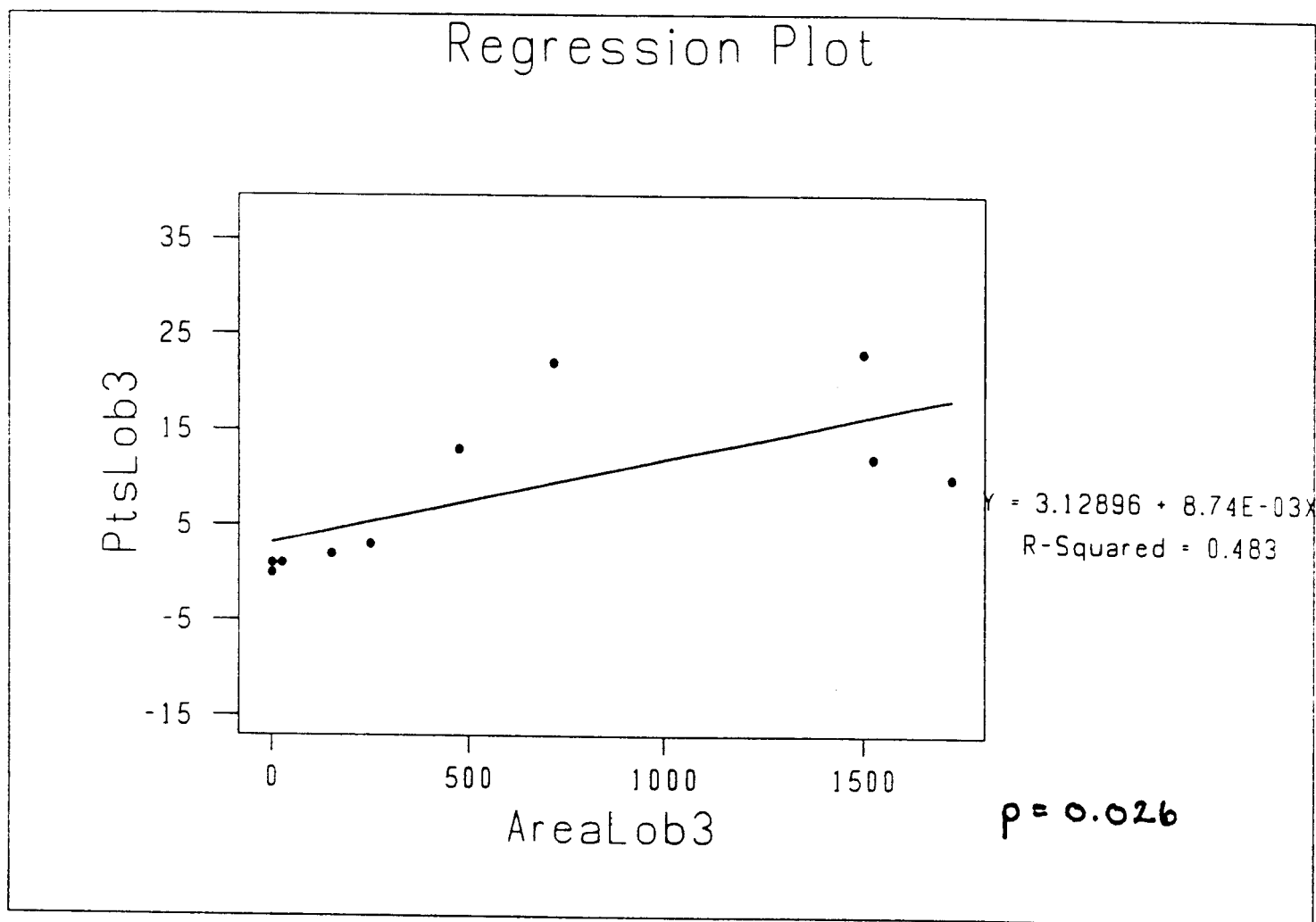


FIG. 20

Richardsons Ocean Center - % Cover Estimation

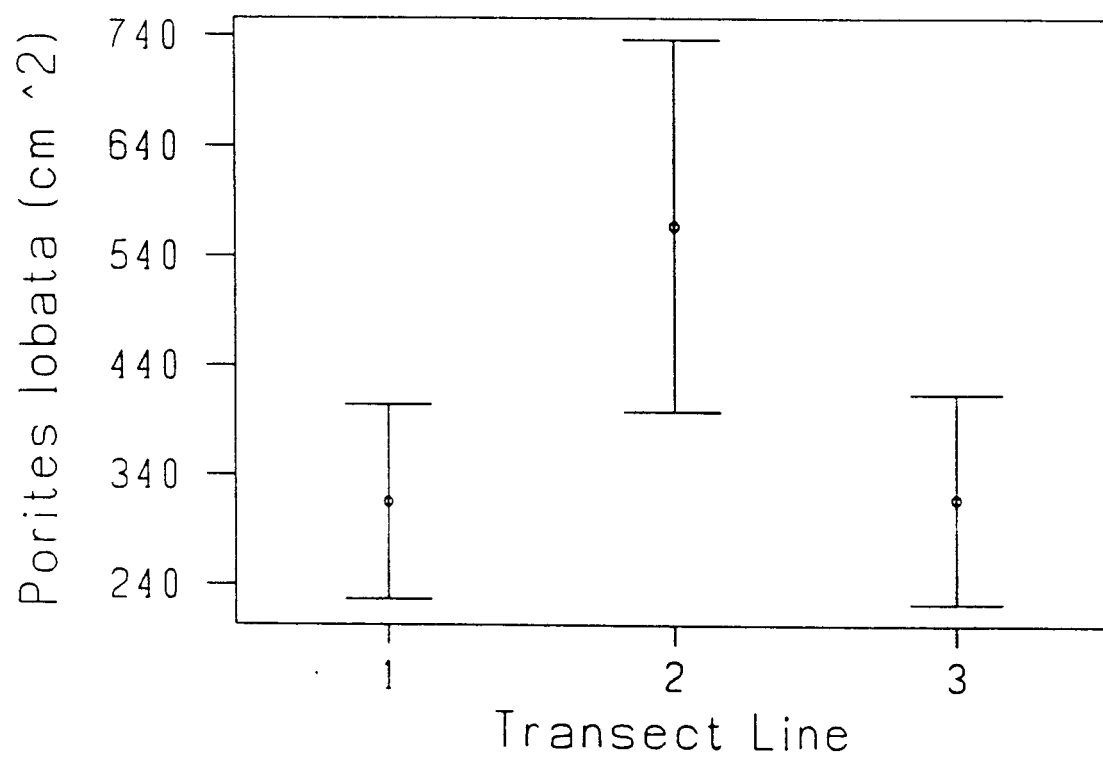


FIG. 21

## Regression Analysis

The regression equation is  
 $\text{SpiroLn2} = 0.65 + 0.373 \text{ PtsLob2}$

Predictor	Coef	Stdev	t-ratio	p
Constant	0.647	1.308	0.49	0.634
PtsLob2	0.37310	0.08846	4.22	0.003

$s = 3.214$        $R\text{-sq} = 69.0\%$        $R\text{-sq(adj)} = 65.1\%$

### Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	183.76	183.76	17.79	0.003
Error	8	82.64	10.33		
Total	9	266.40			

### Unusual Observations

Obs.	PtsLob2	SpiroLn2	Fit	Stdev.Fit	Residual	St.Resid
10	30.0	6.30	11.84	2.09	-5.54	-2.27R

R denotes an obs. with a large st. resid.

```
MTB > %Fitline 'SpiroLn1' 'PtsLob1';
SUBC> Confidence 95.0.
Executing from file: C:\MTBWIN\MACROS\Fitline.MAC
```

```
Macro is running ... please wait
MTB > Regress 'SpiroLn3' 1 'PtsLob3';
SUBC> Constant.
```

## Regression Analysis

The regression equation is  
 $\text{SpiroLn3} = 0.77 + 0.291 \text{ PtsLob3}$

Predictor	Coef	Stdev	t-ratio	p
Constant	0.769	1.277	0.60	0.564
PtsLob3	0.2910	0.1063	2.74	0.026

$s = 2.781$        $R\text{-sq} = 48.4\%$        $R\text{-sq(adj)} = 41.9\%$

### Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	57.948	57.948	7.49	0.026
Error	8	61.893	7.737		
Total	9	119.841			

```
MTB > %Fitline 'SpiroLn3' 'PtsLob3';
SUBC> Confidence 95.0.
Executing from file: C:\MTBWIN\MACROS\Fitline.MAC
```

```
Macro is running ... please wait
MTB > Save 'C:\MTBWIN\LHDATA\ROC-CORR.MTW';
SUBC> Replace.
Saving worksheet in file: C:\MTBWIN\LHDATA\ROC-CORR.MTW
* NOTE * Existing file replaced.
MTB > Save 'C:\MTBWIN\LHDATA\ROC-CORR.MTW';
SUBC> Replace.
Saving worksheet in file: C:\MTBWIN\LHDATA\ROC-CORR.MTW
* NOTE * Existing file replaced.
MTB > Regress 'PtsLob1' 1 'AreaLob1';
SUBC> Constant.
```



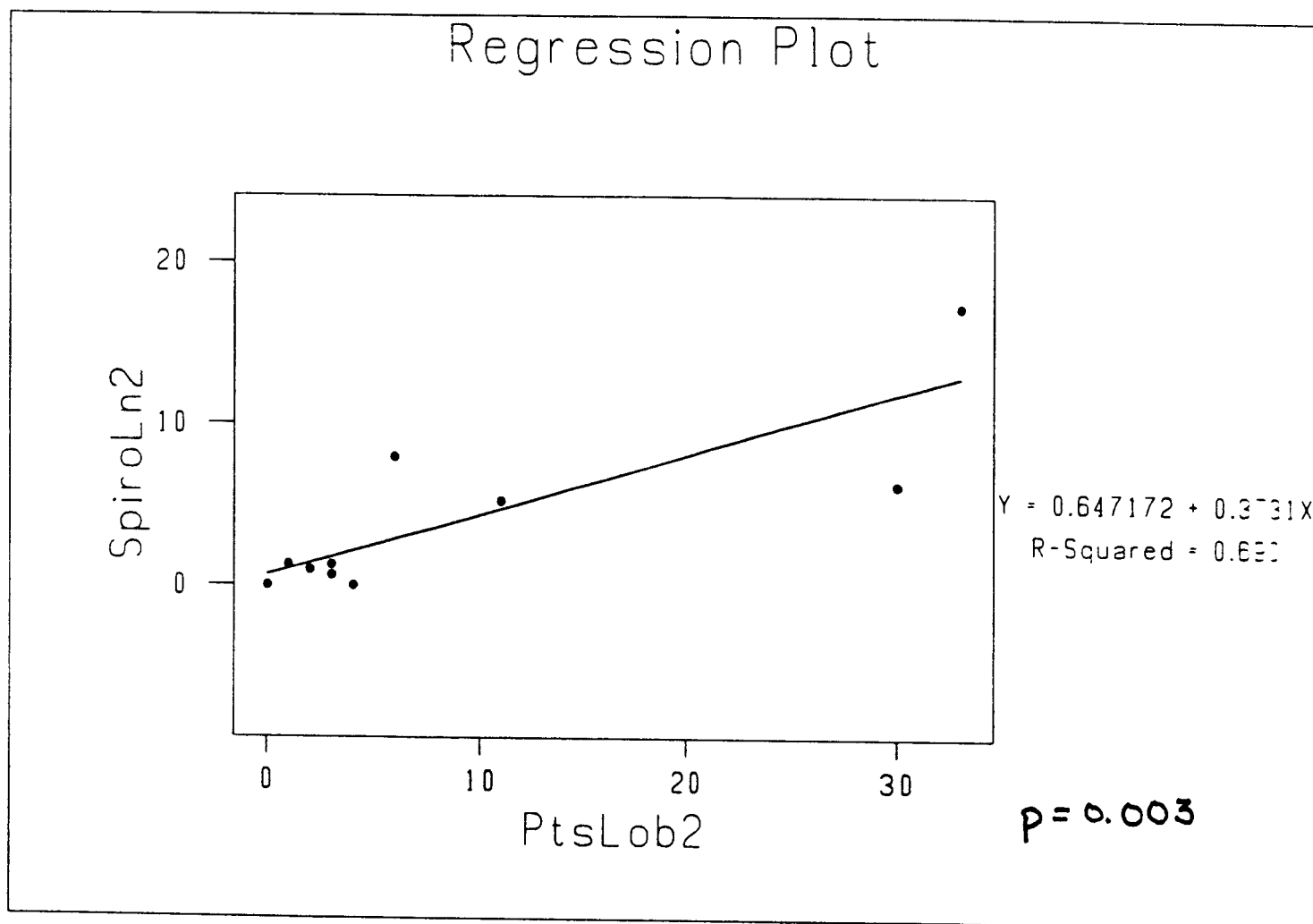


FIG. 23

# Macroinvertebrate Abundances

## Richardsons Ocean Center

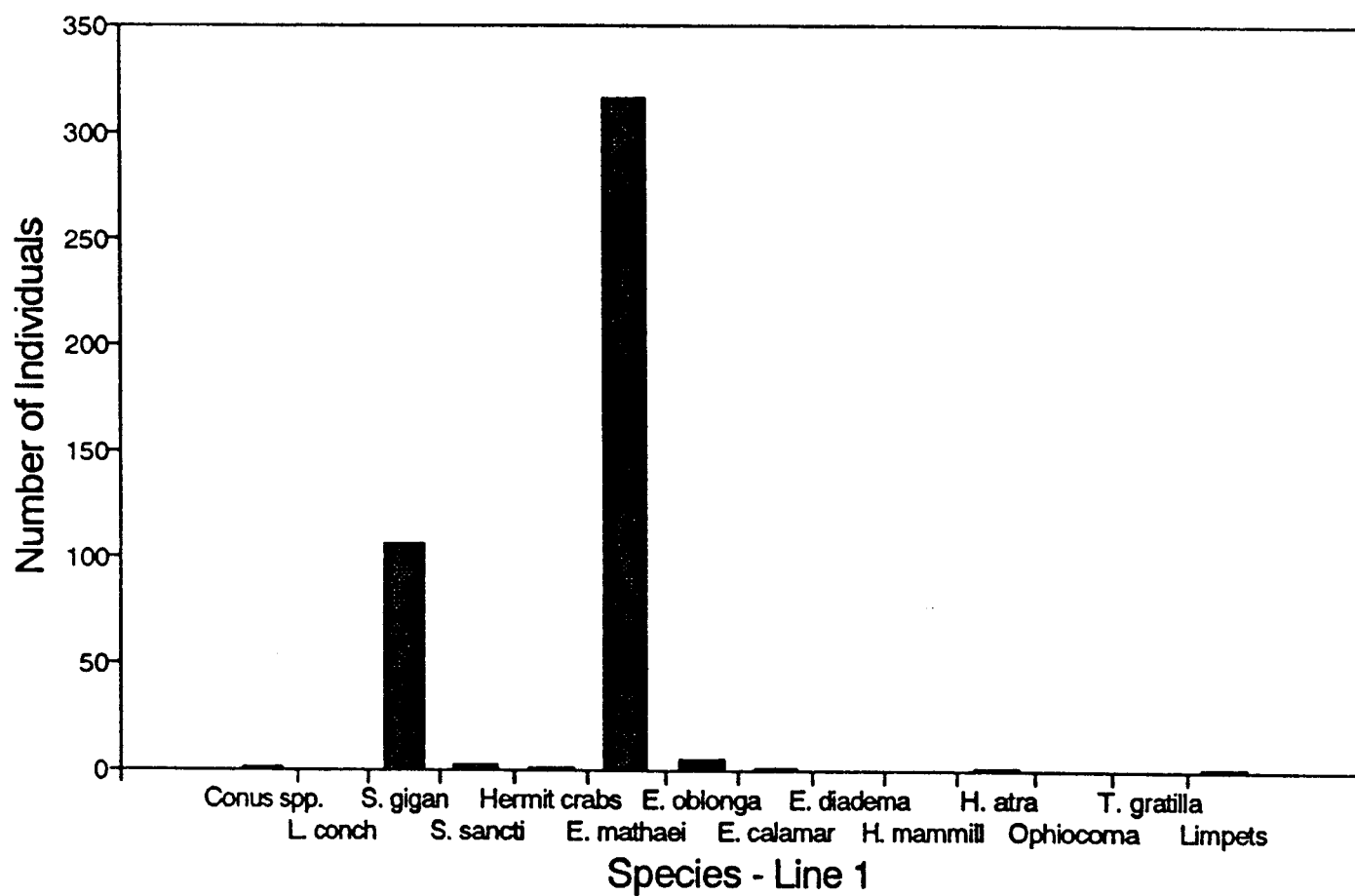


FIG. 24

# Macroinvertebrate Abundances

## Richardsons Ocean Center

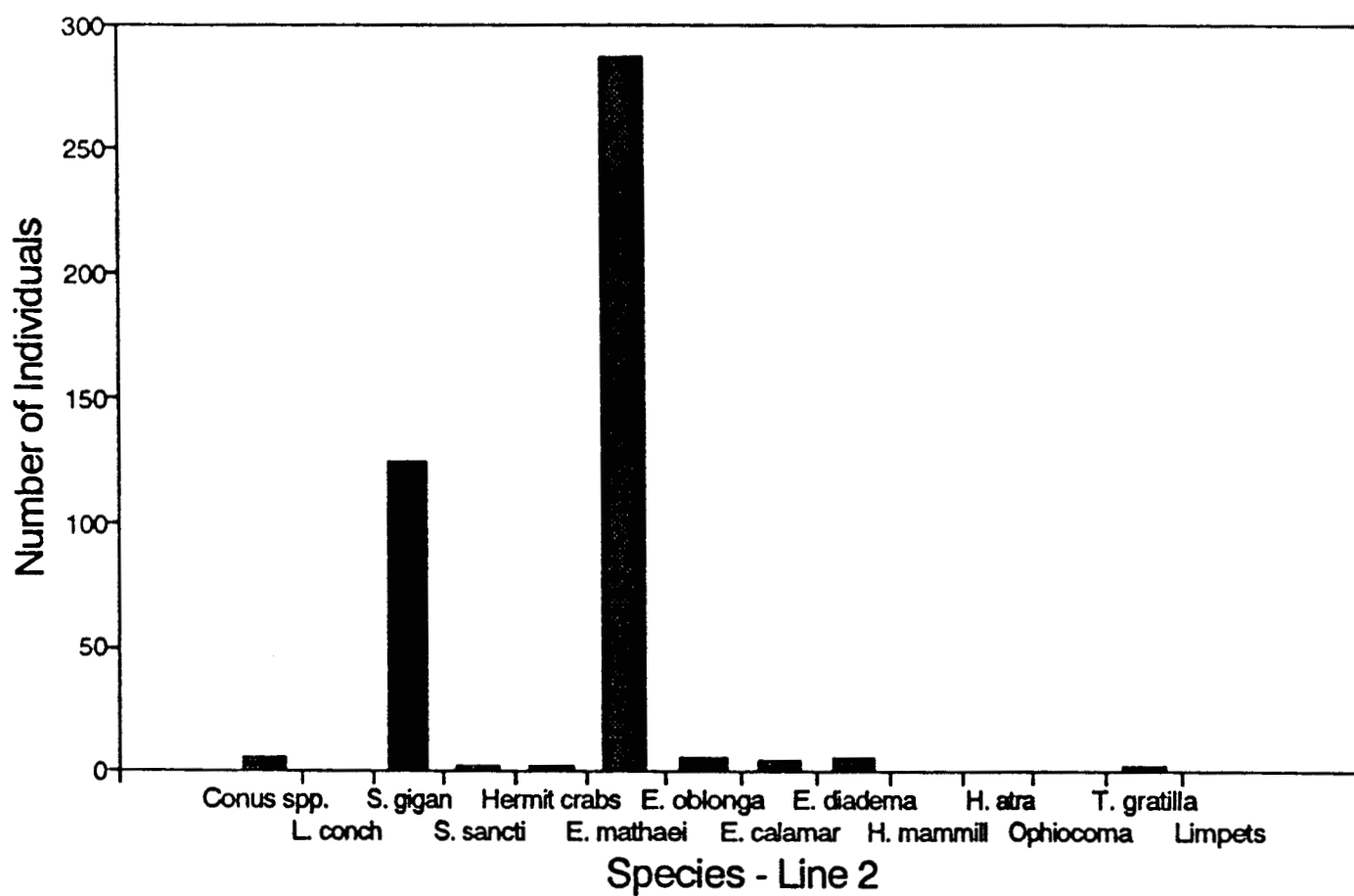


FIG. 25

# Macroinvertebrate Abundances

## Richardsons Ocean Center

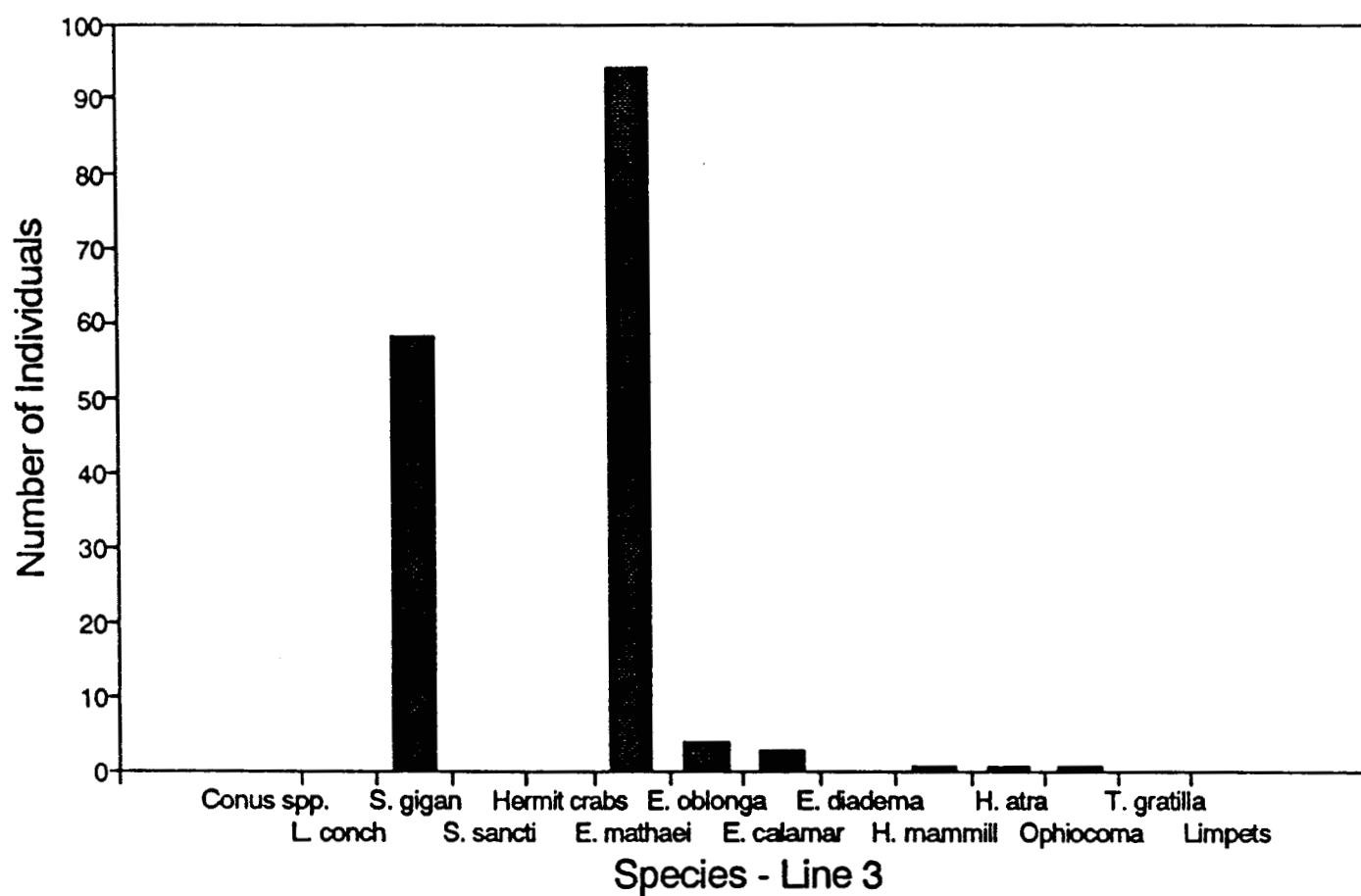


FIG. 26

# Macroinvertebrate Abundances

## Richardsons Ocean Center

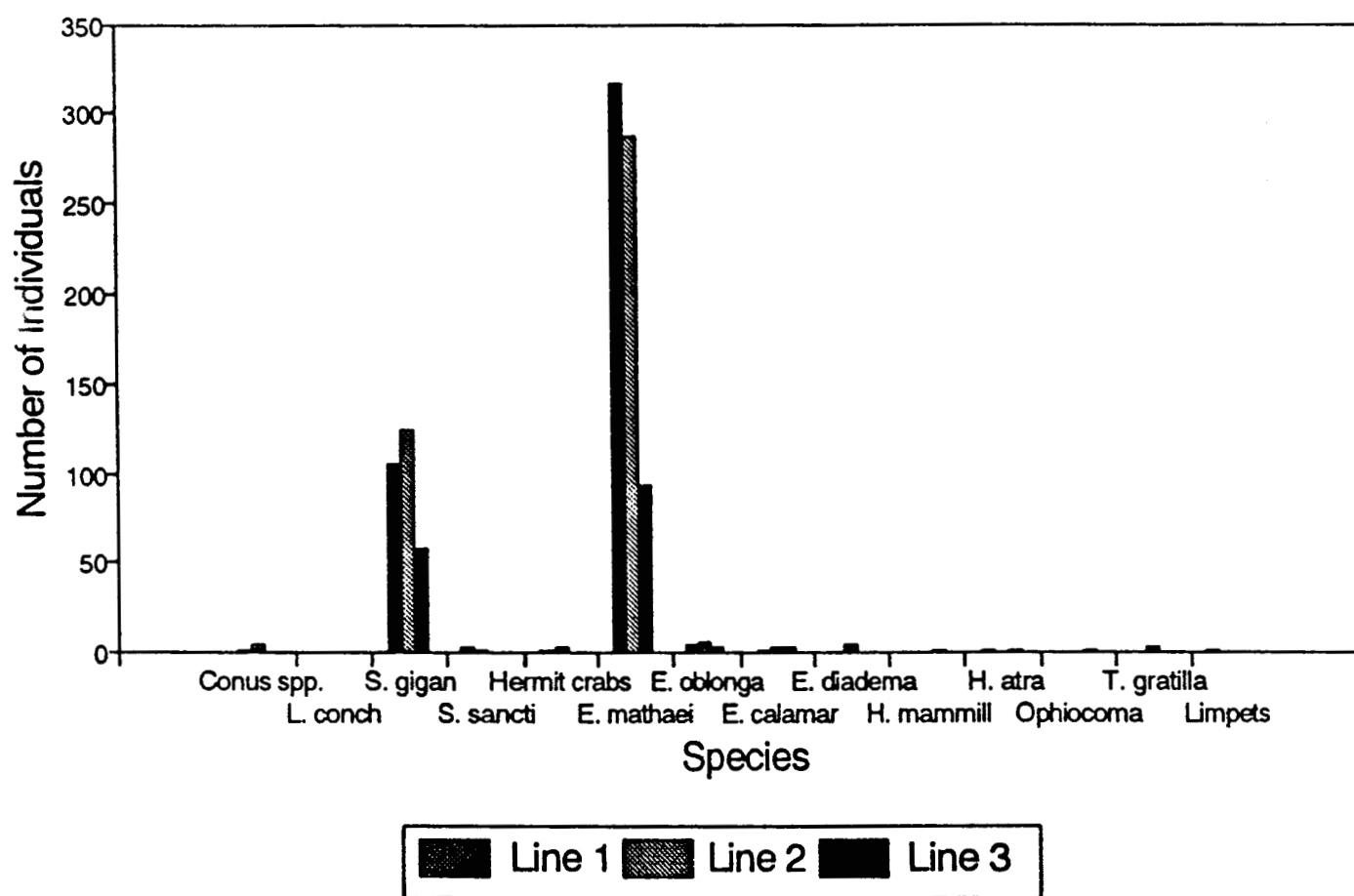


FIG. 27

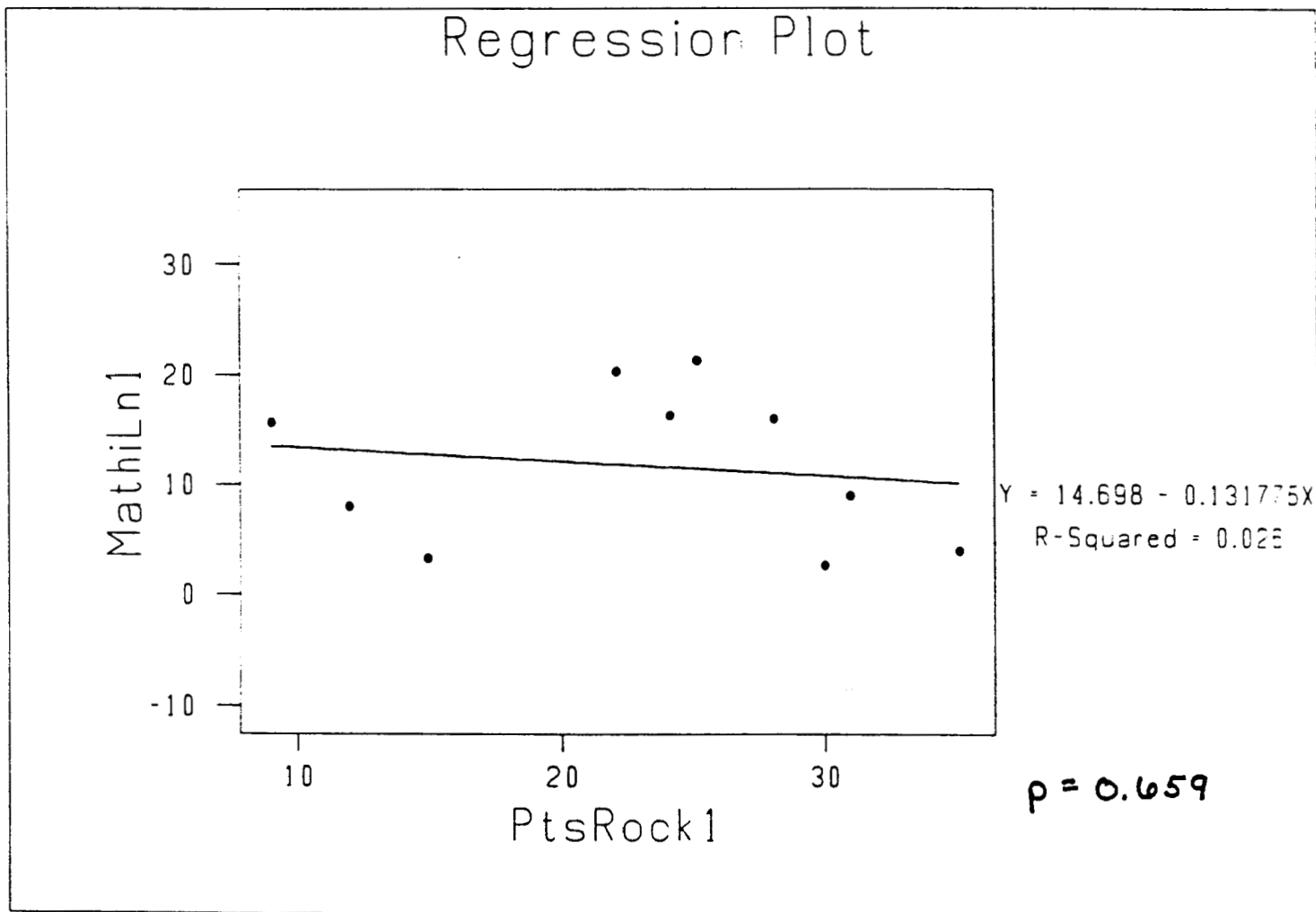


FIG. 28

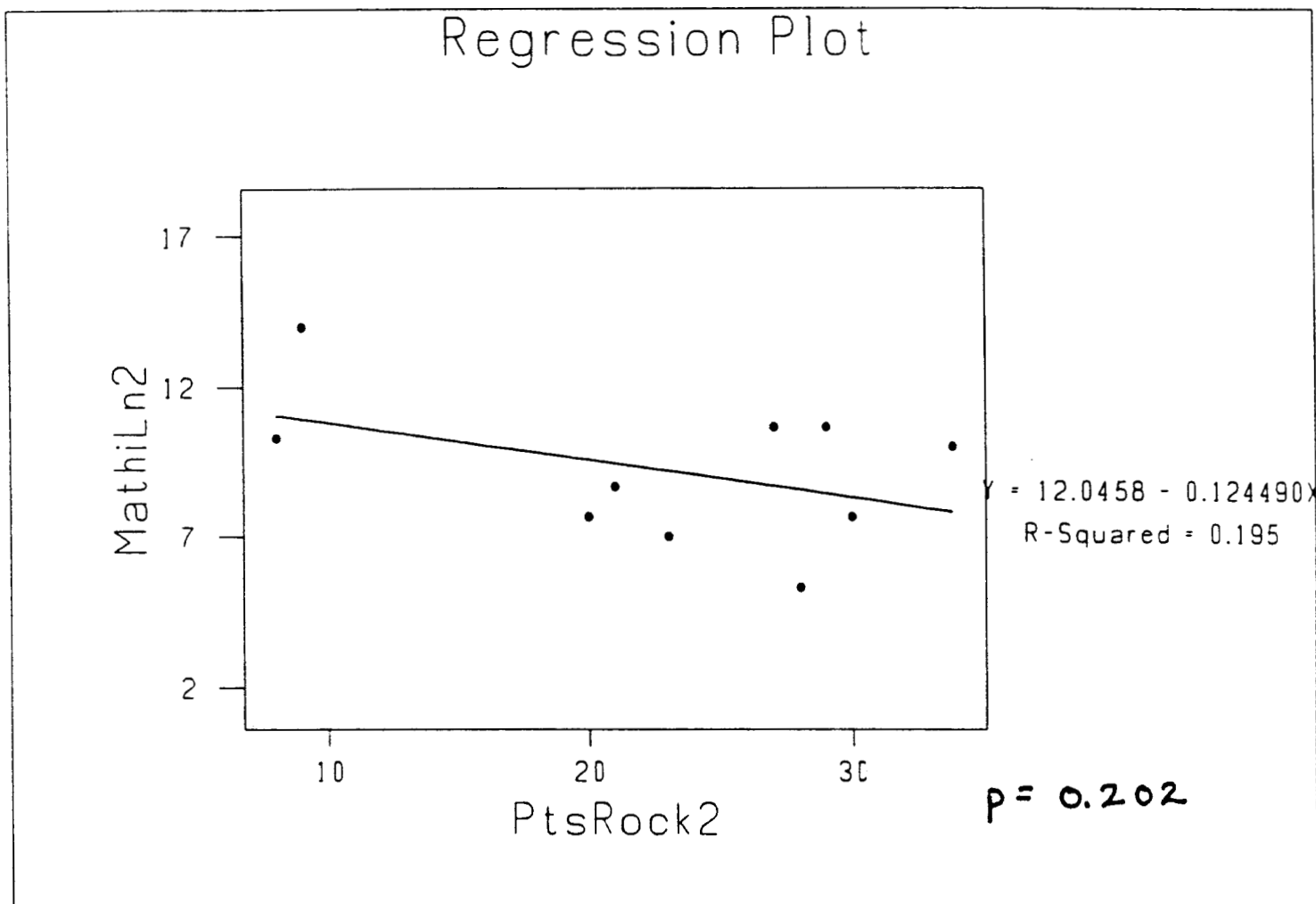


FIG. 29

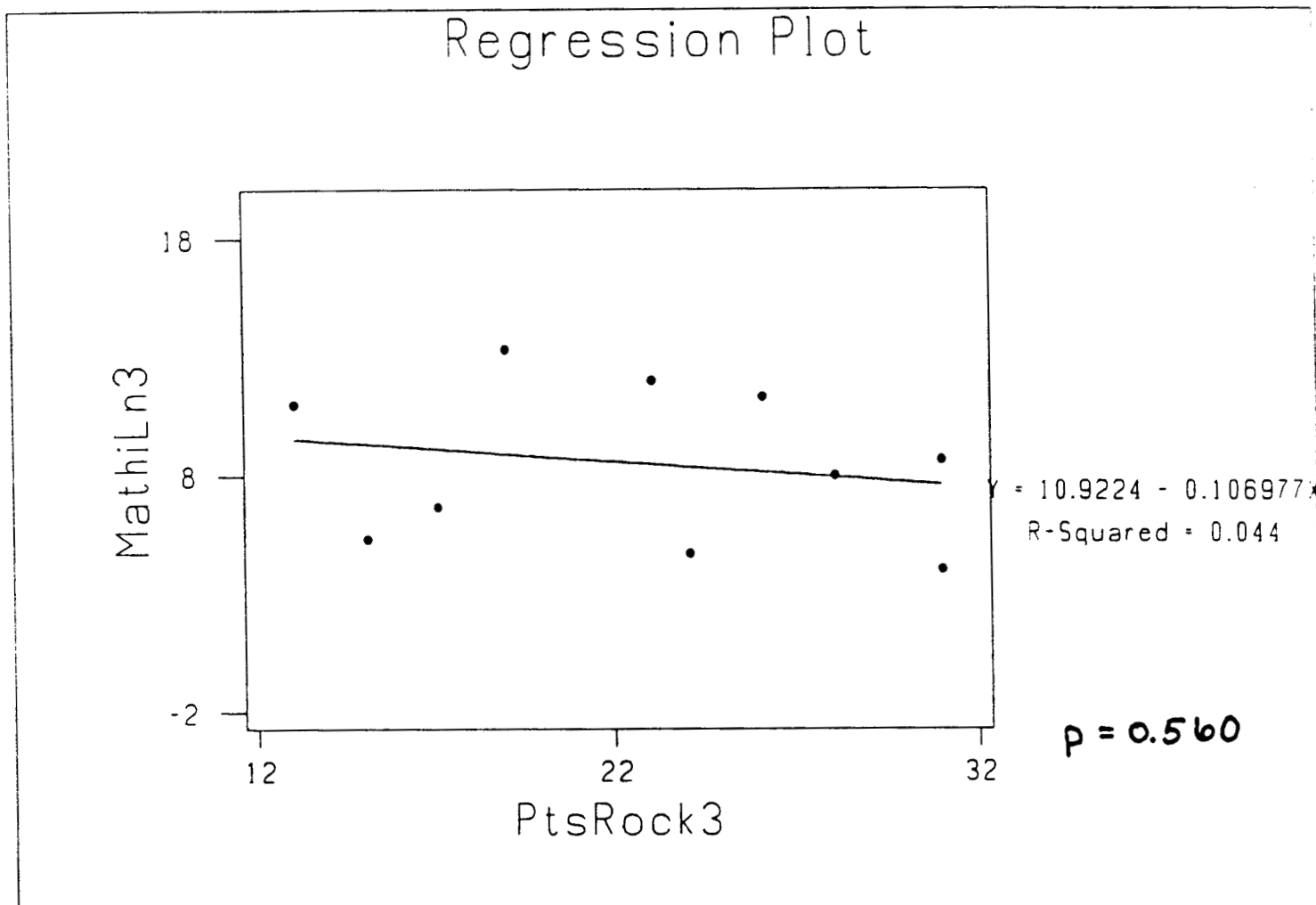


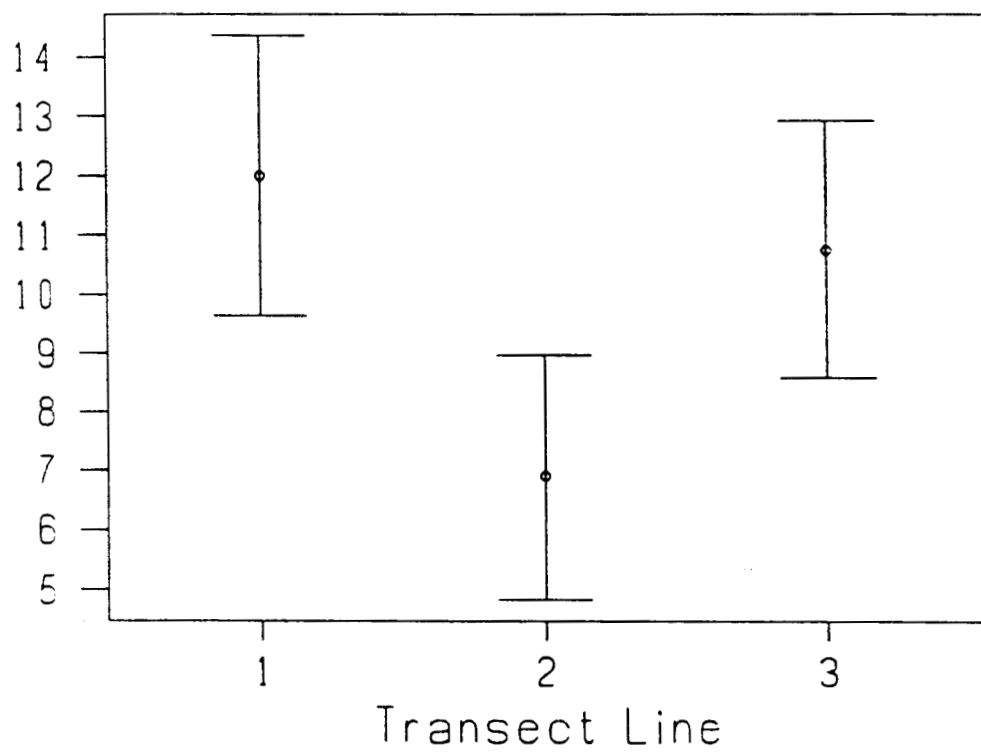
FIG. 30



## *APPENDIX I*

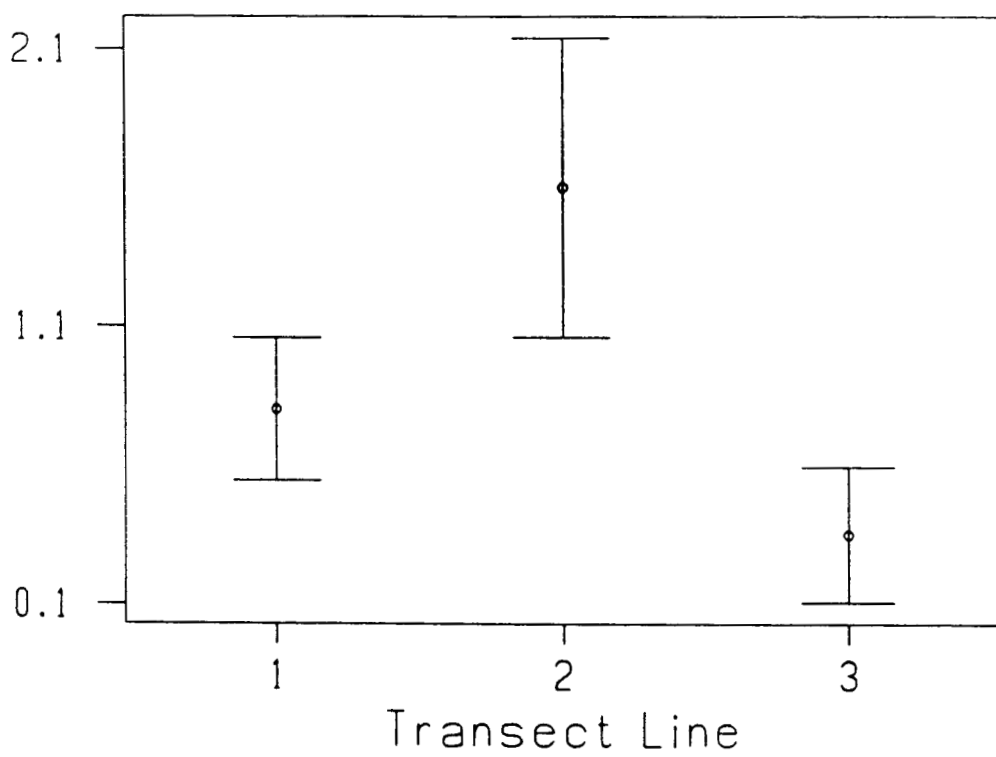
Richardsons Ocean Center - Photoquadrant

Porites lobata (Random Points)



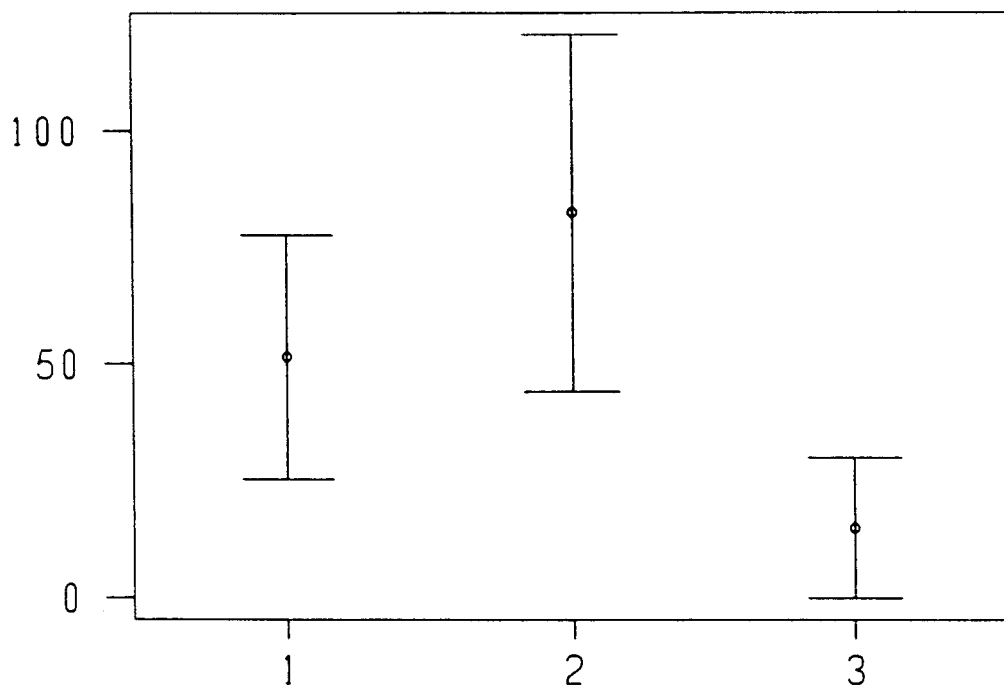
Pocillopora meandrina (Random Points)

# Richardsons Ocean Center - Photoquadrant



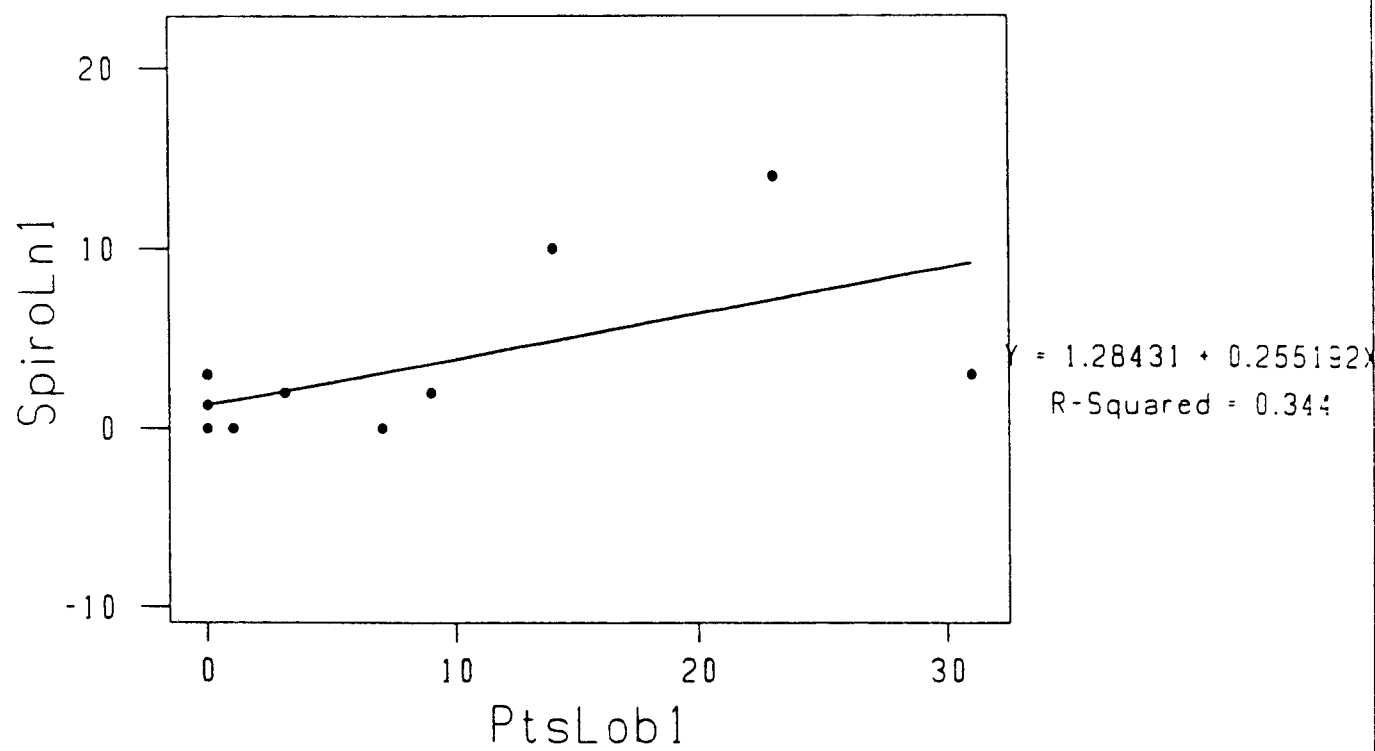
# Richardsons Ocean Center - % Cover Estimation

Pocillopora meandrina (cm ^2)

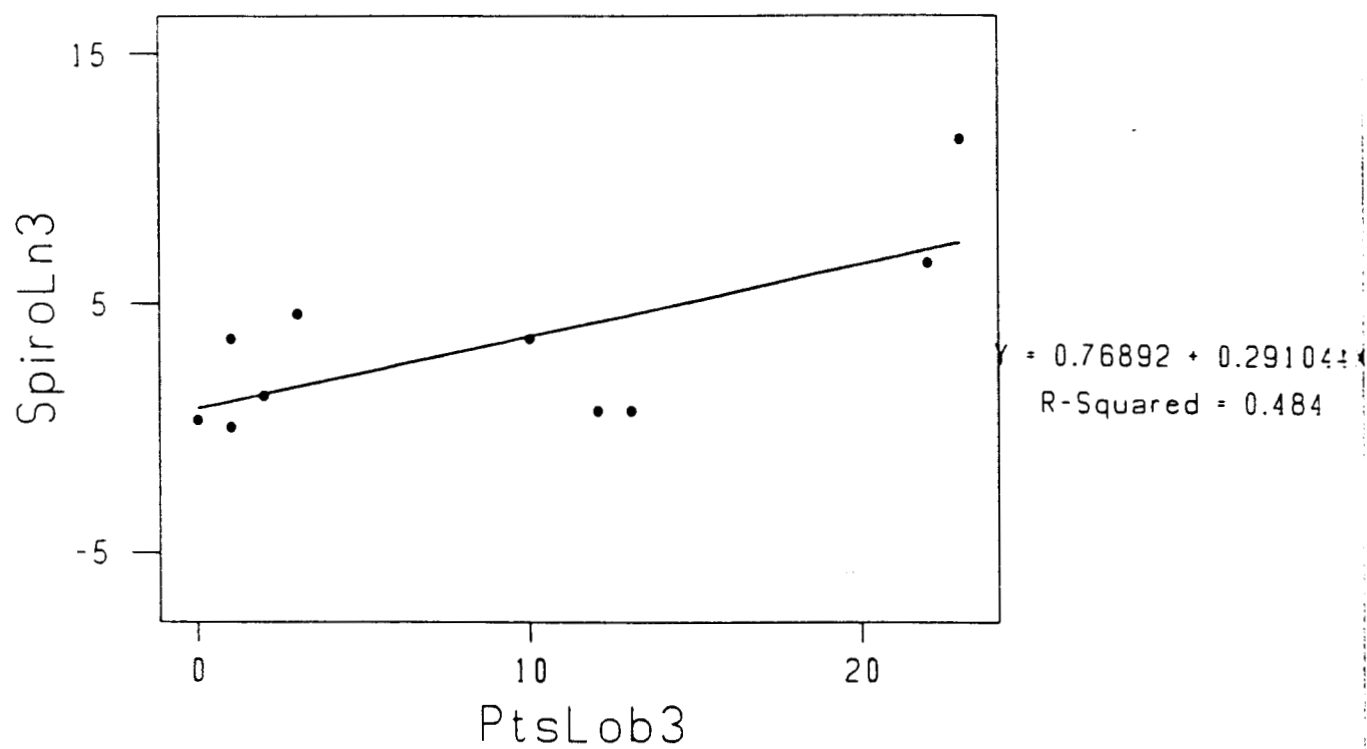


Transect Line

# Regression Plot



# Regression Plot



## *APPENDIX II*

Worksheet size: 100000 cells

```
MTB > Retrieve 'A:\ROC-AREA.MTW'.
Retrieving worksheet from file: A:\ROC-AREA.MTW
Worksheet was saved on 7/14/1995
MTB > Erase C1-C1000
MTB > Erase K1-K1000
MTB > Erase M1-M100
MTB > Let K998 = '.'
MTB > Let K999 = 2.7182818
MTB > Let K1000 = 3.14159265
MTB > Retrieve 'A:\ROC-AREA.MTW'.
Retrieving worksheet from file: A:\ROC-AREA.MTW
Worksheet was saved on 7/14/1995
MTB > AOVOneway 'lob-1' 'comp-1' 'mean-1' 'rock-1' 'dead-1' 'verr-1' &
CONT> 'sand-1'.
```

## One-Way Analysis of Variance

### Analysis of Variance

Source	DF	SS	MS	F	p
Factor	9	53175996	5908444	80.86	0.000
Error	190	13883062	73069		
Total	199	67059060			

Individual 95% CIs For Mean  
Based on Pooled StDev

Level	N	Mean	StDev
lob-1	20	315.7	396.5
comp-1	20	1.3	5.6
mean-1	20	51.5	116.9
verr-1	20	46.0	111.0
dead-1	20	44.5	89.7
sand-1	20	246.6	331.6
rock-1	20	1798.2	547.0
dead-1	20	44.5	89.7
verr-1	20	46.0	111.0
sand-1	20	246.6	331.6

Pooled StDev = 270.3

MTB > AOVOneway 'lob-1' 'comp-1' 'mean-1' 'verr-1' 'dead-1' 'sand-1'.

## One-Way Analysis of Variance

### Analysis of Variance

Source	DF	SS	MS	F	p
Factor	5	1684982	336996	6.71	0.000
Error	114	5722685	50199		
Total	119	7407667			

Individual 95% CIs For Mean  
Based on Pooled StDev

Level	N	Mean	StDev
lob-1	20	315.7	396.5
comp-1	20	1.3	5.6
mean-1	20	51.5	116.9
verr-1	20	46.0	111.0
dead-1	20	44.5	89.7
sand-1	20	246.6	331.6

Pooled StDev = 224.1

MTB > AOVOneway 'lob-1' 'mean-1' 'verr-1' 'dead-1'.

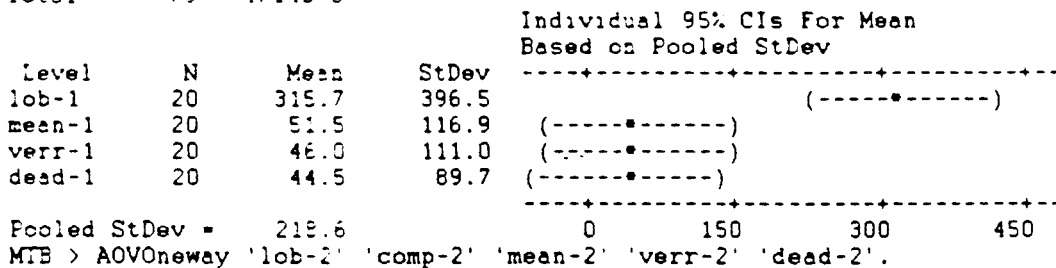
## One-Way Analysis of Variance

### Analysis of Variance

Source	DF	SS	MS	F	p
Factor	3	1080867	360289	7.54	0.000
Error	76	3633202	47805		



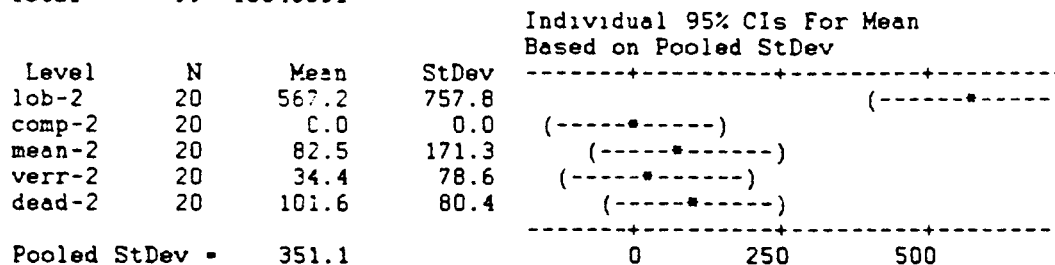
Total 79 4714070



## One-Way Analysis of Variance

### Analysis of Variance

Source	DF	SS	MS	F	p
Factor	4	4331262	1082816	8.79	0.000
Error	95	11709339	123256		
Total	99	16040601			



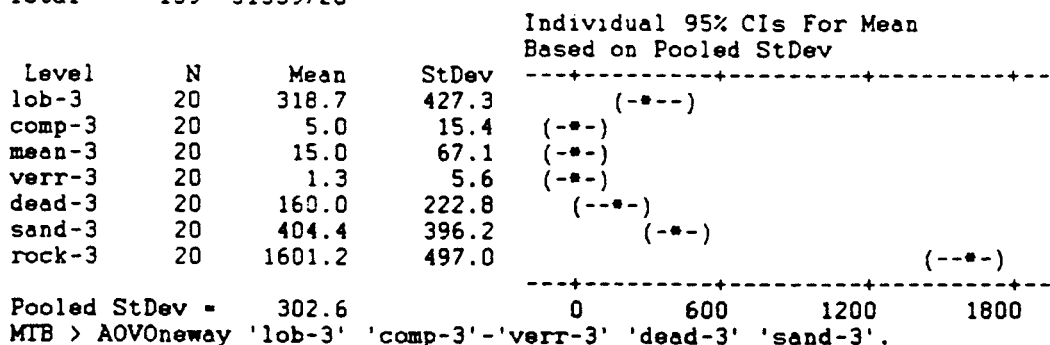
\* NOTE \* All values in column are identical.

MTB > AOVOneway 'lob-3' 'comp-3' 'mean-3' 'verr-3' 'dead-3' 'sand-3' &  
CONT> 'rock-3'.

## One-Way Analysis of Variance

### Analysis of Variance

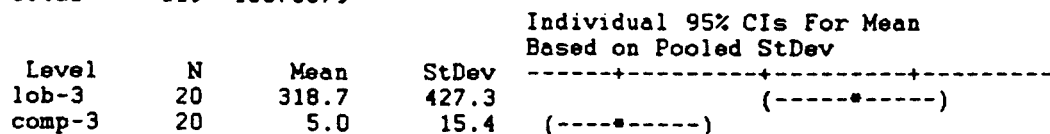
Source	DF	SS	MS	F	p
Factor	6	39161932	6526988	71.28	0.000
Error	133	12177788	91562		
Total	139	51339720			



## One-Way Analysis of Variance

### Analysis of Variance

Source	DF	SS	MS	F	p
Factor	5	3093385	618677	9.42	0.000
Error	114	7484694	65655		
Total	119	10578079			



	mean-3	20	15.0	67.1	(-----*-----)
	verr-3	20	1.3	5.6	(-----*-----)
	dead-3	20	160.0	222.8	(-----*-----)
	sand-3	20	404.4	396.2	(-----*-----)

Pooled StDev = 256.2

MTB > AOVOneway 'lob-3' 'verr-3' 'dead-3' 'mean-3' 'comp-3'.

## One-Way Analysis of Variance

### Analysis of Variance

Source	DF	SS	MS	F	p
Factor	6	1781491	296915	8.60	0.000
Error	133	4592188	34528		
Total	139	6373679			

### Individual 95% CIs For Mean Based on Pooled StDev

Level	N	Mean	StDev
lob-3	20	318.7	427.3
comp-3	20	5.0	15.4
mean-3	20	15.0	67.1
verr-3	20	1.3	5.6
dead-3	20	160.0	222.8
mean-3	20	15.0	67.1
comp-3	20	5.0	15.4

Pooled StDev = 185.8

MTB > AOVOneway 'lob-3' 'comp-3' 'mean-3' 'verr-3' 'dead-3'.

## One-Way Analysis of Variance

### Analysis of Variance

Source	DF	SS	MS	F	p
Factor	4	1549062	387266	8.17	0.000
Error	95	4502188	47391		
Total	99	6051250			

### Individual 95% CIs For Mean Based on Pooled StDev

Level	N	Mean	StDev
lob-3	20	318.7	427.3
comp-3	20	5.0	15.4
mean-3	20	15.0	67.1
verr-3	20	1.3	5.6
dead-3	20	160.0	222.8

Pooled StDev = 217.7

MTB > Erase C1-C1000

MTB > Erase K1-K1000

MTB > Erase M1-M100

MTB > Let K998 = '\*'

MTB > Let K999 = 2.7182818

MTB > Let K1000 = 3.14159265

MTB > Retrieve 'A:\PHOTO.MTW'.

Retrieving worksheet from file: A:\PHOTO.MTW

Worksheet was saved on 7/14/1995

MTB > AOVOneway 'L-1'-'-'-'1'.

## One-Way Analysis of Variance

### Analysis of Variance

Source	DF	SS	MS	F	p
Factor	15	10386.3	692.4	46.92	0.000
Error	304	4486.7	14.8		
Total	319	14873.0			

### Individual 95% CIs For Mean Based on Pooled StDev

Level	N	Mean	StDev
L-1	20	12.000	10.573

F-1	20	0.100	0.447	(-*)
C-1	20	0.800	1.152	(-*)
R-1	20	0.000	0.000	(-*)
B-1	20	0.800	1.765	(-*)
P-1	20	0.100	0.447	(-*)
V-1	20	0.000	0.000	(-*)
E-1	20	0.000	0.000	(-*)
O-1	20	0.000	0.000	(-*)
U-1	20	4.050	3.348	(-*)
I-1	20	0.000	0.000	(-*)
A-1	20	2.400	3.185	(-*)
K-1	20	22.000	9.003	(-*)
S-1	20	3.200	3.750	(-*)
DC-1	20	0.950	0.999	(-*)
-/1	20	3.600	1.429	(-*)

Pooled StDev = 3.842

0.0 7.0 14.0 21.0

\* NOTE \* All values in column are identical.

MTB > AOVOneway 'L-2'-'I-2' 'A-2'-'-/2'.

## One-Way Analysis of Variance

Analysis of Variance				
Source	DF	SS	MS	F
Factor	15	11700.4	780.0	74.90
Error	304	3165.9	10.4	0.000
Total	319	14866.2		

Level	N	Mean	StDev	
L-2	20	6.900	9.250	(-*)
F-2	20	0.000	0.000	(-*)
C-2	20	1.600	2.415	(-*)
R-2	20	0.100	0.308	(-*)
B-2	20	0.600	0.883	(-*)
P-2	20	0.000	0.000	(-*)
V-2	20	0.000	0.000	(-*)
E-2	20	0.000	0.000	(-*)
O-2	20	0.000	0.000	(-*)
U-2	20	4.250	1.482	(-*)
I-2	20	0.050	0.224	(-*)
A-2	20	4.900	3.684	(-*)
K-2	20	25.000	6.836	(-*)
S-2	20	4.350	3.281	(-*)
DC-2	20	0.100	0.447	(-*)
-/2	20	2.100	0.912	(-*)

Pooled StDev = 3.227

0.0 8.0 16.0 24.0

\* NOTE \* All values in column are identical.

MTB > AOVOneway 'L-3'-'-/3'.

## One-Way Analysis of Variance

Analysis of Variance				
Source	DF	SS	MS	F
Factor	15	10185.9	679.1	61.64
Error	304	3349.1	11.0	0.000
Total	319	13535.0		

Level	N	Mean	StDev	
L-3	20	10.750	9.722	(-*)
F-3	20	0.000	0.000	(-*)
C-3	20	0.350	1.089	(-*)
R-3	20	0.000	0.000	(-*)

Individual 95% CIs For Mean  
Based on Pooled StDev

0.0 8.0 16.0 24.0

\* NOTE \* All values in column are identical.

MTB > AOVOneway 'L-3'-'O-3' 'DC-3'.

# One-Way Analysis of Variance

## Analysis of Variance

Source	DF	SS	MS	F	p
Factor	9	2035.58	226.18	23.34	0.000
Error	190	1841.20	9.69		
Total	199	3876.78			

Individual 95% CIs For Mean  
Based on Pooled StDev

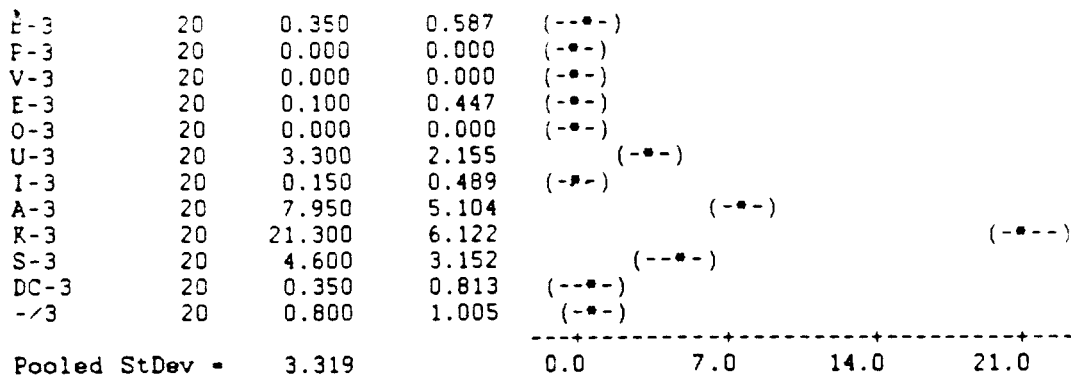
Level	N	Mean	StDev	
L-3	20	10.750	9.722	(---*---)
F-3	20	0.000	0.000	(---*---)
C-3	20	0.350	1.089	(---*---)
R-3	20	0.000	0.000	(---*---)
B-3	20	0.350	0.587	(---*---)
P-3	20	0.000	0.000	(---*---)
V-3	20	0.000	0.000	(---*---)
E-3	20	0.100	0.447	(---*---)
O-3	20	0.000	0.000	(---*---)
DC-3	20	0.350	0.813	(---*---)

Pooled StDev = 3.113

0.0 4.0 8.0 12.0

\* NOTE \* All values in column are identical.

MTB >



\* NOTE \* All values in column are identical.

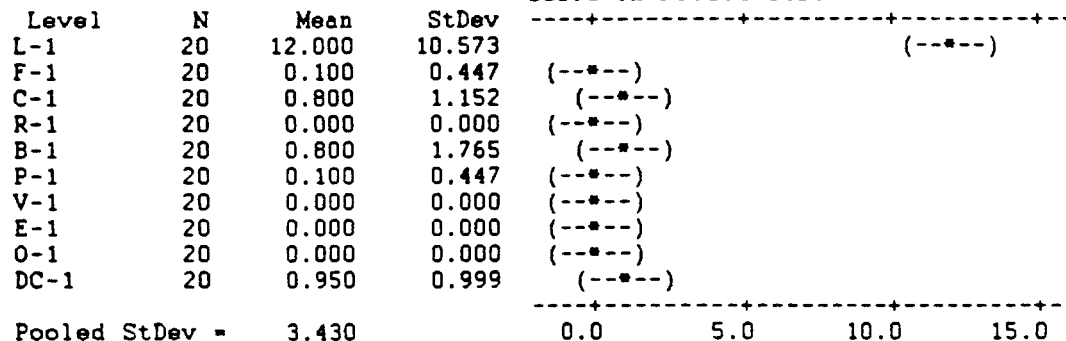
MTB > AOVOneway 'L-1'-'O-1' 'DC-1'.

## One-Way Analysis of Variance

### Analysis of Variance

Source	DF	SS	MS	F	p
Factor	9	2488.9	276.5	23.51	0.000
Error	190	2234.9	11.8		
Total	199	4723.9			

Individual 95% CIs For Mean  
Based on Pooled StDev



\* NOTE \* All values in column are identical.

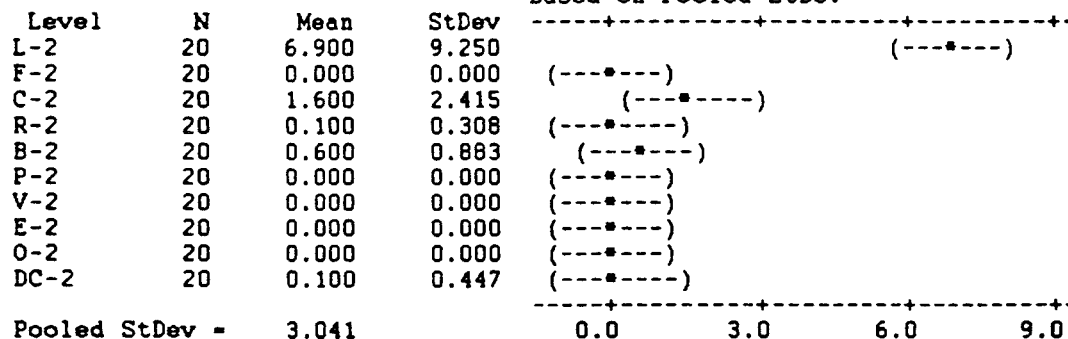
MTB > AOVOneway 'L-2'-'O-2' 'DC-2'.

## One-Way Analysis of Variance

### Analysis of Variance

Source	DF	SS	MS	F	p
Factor	9	838.02	93.11	10.07	0.000
Error	190	1757.00	9.25		
Total	199	2595.02			

Individual 95% CIs For Mean  
Based on Pooled StDev



Based on Pooled StDev

Level	N	Mean	StDev
L-1	20	12.000	10.573
L-2	20	6.900	9.250
L-3	20	10.750	9.722

Pooled StDev = 9.864  
MTB > AOVOneway 'K-1' 'K-2' 'K-3'.

## One-Way Analysis of Variance

Analysis of Variance

Source	DF	SS	MS	F	p
Factor	2	154.5	77.3	1.40	0.254
Error	57	3140.2	55.1		
Total	59	3294.7			

Individual 95% CIs For Mean  
Based on Pooled StDev

Level	N	Mean	StDev
K-1	20	22.000	9.003
K-2	20	25.000	6.836
K-3	20	21.300	6.122

Pooled StDev = 7.422  
MTB > Erase C1-C1000  
MTB > Erase K1-K1000  
MTB > Erase M1-M100  
MTB > Let K998 = '.'  
MTB > Let K999 = 2.7182818  
MTB > Let K1000 = 3.14159265  
MTB > Retrieve 'A:\INVT-1.MTW'.  
Retrieving worksheet from file: A:\INVT-1.MTW  
Worksheet was saved on 7/14/1995  
MTB > AOVOneway 'Spiro-1' 'Spiro-2' 'Spiro-3'.

## One-Way Analysis of Variance

Analysis of Variance

Source	DF	SS	MS	F	p
Factor	2	10.4	5.2	0.16	0.852
Error	87	2829.6	32.5		
Total	89	2840.0			

Individual 95% CIs For Mean  
Based on Pooled StDev

Level	N	Mean	StDev
Spiro-1	30	3.533	5.264
Spiro-2	30	4.133	6.887
Spiro-3	30	3.333	4.737

Pooled StDev = 5.703  
MTB > AOVOneway 'Mathae-1' 'Mathae-2' 'Mathae-3'.

## One-Way Analysis of Variance

Analysis of Variance

Source	DF	SS	MS	F	p
Factor	2	56.1	28.0	0.62	0.539
Error	87	3918.0	45.0		
Total	89	3974.1			

Individual 95% CIs For Mean  
Based on Pooled StDev

Level	N	Mean	StDev
Mathae-1	30	10.533	8.792
Mathae-2	30	9.567	5.418
Mathae-3	30	8.600	5.334

Pooled StDev = 6.711  
MTB >

1	20	315.7	396.5	(-----*-----)
2	20	567.2	757.8	(-----*-----)
3	20	318.7	427.3	(-----*-----)
Pooled StDev = 552.0				-----+-----+-----+
				250 500 750

